

TR-398

Wi-Fi Residential & SOHO Performance Testing

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Executive Summary

TR-398 provides a set of performance test cases with pass/fail requirements for 802.11n/ac/ax implementations according to Institute of Electrical and Electronics Engineers (IEEE) specification 802.11 [1].

The primary goal of TR-398 is to provide a standard set of test cases and framework to measure aspect of the performance between Access Point (AP) (e.g., a CPE with Wi-Fi), one or more reference Stations (STA) (e.g., Personal Computer [PC], integrated testing equipment, etc.), and if applicable, one Wi-Fi repeater, under controlled laboratory conditions. The test cases are defined for a Device Under Test (DUT – AP only), tested against one or more STA(s).

Technical contents of TR-398 test plan include test setup information, equipment configuration requirements, test procedures, and pass/fail requirements for each test case.

Issue 2 of this test plan updates a number of the test cases, adds additional test cases for mesh and Wi-Fi roaming between APs, and the new 802.11ax technology.

Issue 2 Corrigendum 1 of this test plan makes corrections to several of the test cases, in support of the Broadband Forum BBF.398 Grade Wi-Fi Program.

Issue 3 of this test plan adds the following augmentations:

- Description and requirements for the calibration and tuning of the RF path loss in the test setup.
- Updates the test metrics to account for changes in the path loss.
- Adds additional test cases and requirements for Wi-Fi6E (6 GHz).
- Moves Mesh and Roaming test cases into main body of this test plan.
- Adds new test cases for parameter accuracy.

1 Purpose and Scope

1.1 Purpose

TR-398 provides a set of performance test cases with pass/fail requirements for 802.11n/ac/ax implementations, to assist operators in the selection of Wi-Fi capable devices. Operators will use additional criteria, such as deployment scenarios, customer needs, complexity, when selecting equipment and defining deployment configurations. These test cases are not suitable for consumer selection of devices in the absence of expert level understanding of Wi-Fi operation, configurations, and deployment scenarios. The corresponding certification programs of interoperability are “Wi-Fi 4” “Wi-Fi 5”, “Wi-Fi 6” and “Wi-Fi 6e” for 802.11n, 802.11ac, and 802.11ax in Wi-Fi Alliance, respectively.

The primary goal of TR-398 Issue 3 is to provide a standard set of test cases and framework to measure aspects of the performance between AP (e.g., a CPE with Wi-Fi), one or more reference STA (e.g., PC, integrated testing equipment, etc.), and if applicable, one Wi-Fi repeater, under controlled laboratory conditions. The test cases are defined for a Device Under Test (DUT – AP only), tested against a or a set of STA. The DUT SHOULD NOT be a reference design and SHOULD contain the necessary system functionality to execute this test plan (see section 5)

Technical content in this test plan includes test setup information, equipment configuration requirements, test procedures, and pass/fail requirements for each test case. Specific manufacturer information for test and measurement has not been included in this document, except in cases where the selection or use of alternate equipment could negatively impact the results of the testing.

1.2 Scope

This Technical Report intends to provide a performance test plan for “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 specification”. TR-398 Issue 3 is specifically developed for 802.11n/ac/ax compliant access point devices. The performance of Wi-Fi station (STA) is not in the scope of this project.

Wi-Fi Access Point devices are used in a wide variety of premises which contain many elements which will influence Wi-Fi performance. TR-398 Issue 3 is intended to address a generalized set of performance test cases performed in a controlled laboratory environment. The performance test cases are intended for the access point, to verify:

- 1) RF capability
- 2) Throughput performance
- 3) Spatial consistency
- 4) Airtime fairness
- 5) Connection capability
- 6) Stability/Robustness
- 7) Multiple AP scenarios (mesh & roaming)
- 8) Parameter reporting accuracy

Issue 2 of this test plan makes the following changes and provides the listed additional tests:

- Addition of testing and associated metrics for 802.11ax to all applicable test cases
- Updates to attenuation levels for tests using the “medium” and “long” distances
- New test case for “Dual-band Throughput”
- New test case for “Bidirectional Throughput”
- New test cases for “ Wi-Fi Extender Performance”

- New test case for “Basic Roaming Performance”
- New test case for “Channel Auto-selection”
- New test case for “802.11ax Peak Performance”

Issue 2 Corrigendum 1 makes corrections and changes to the following tests:

- 802.11ax Peak Performance Test
- Spatial Consistency Test
- AP Coexistence Test
- Air-time Fairness Test

Issue 3 makes the following changes and updates to this test plan:

- Description and requirements for the calibration and tuning of the RF path loss in the test setup.
- Updates the test metrics to account for changes in the path loss.
- Adds additional test cases and requirements for Wi-Fi6E (6 GHz).
- Moves Mesh and Roaming test cases into the main body of this test plan.
- Adds new test cases for parameter accuracy.

2 References and Terminology

2.1 Conventions

In this Technical Report, several words are used to signify the requirements of the specification. These words are always capitalized. More information can be found in RFC 2119 [2].

- SHALL** This word, or the term “REQUIRED”, means that the definition is an absolute requirement of the specification.
- SHALL NOT** This phrase means that the definition is an absolute prohibition of the specification.
- SHOULD** This word, or the term “RECOMMENDED”, means that there could exist valid reasons in particular circumstances to ignore this item, but the full implications need to be understood and carefully weighed before choosing a different course.
- SHOULD NOT** This phrase, or the phrase "NOT RECOMMENDED" means that there could exist valid reasons in particular circumstances when the particular behavior is acceptable or even useful, but the full implications need to be understood and the case carefully weighed before implementing any behavior described with this label.
- MAY** This word, or the term “OPTIONAL”, means that this item is one of an allowed set of alternatives. An implementation that does not include this option SHALL be prepared to inter-operate with another implementation that does include the option.

2.2 References

The following references are of relevance to this Technical Report. At the time of publication, the editions indicated were valid. All references are subject to revision; users of this Technical Report are therefore encouraged to investigate the possibility of applying the most recent edition of the references listed below.

A list of currently valid Broadband Forum Technical Reports is published at www.broadband-forum.org.

Document	Title	Source	Year
[1] 802.11	<i>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 specification</i>	IEEE	2020
[2] RFC 2119	<i>Key words for use in RFCs to Indicate Requirement Levels</i>	IEEE	1997
[3] 802.11ax	<i>IEEE Standard for Information Technology-- Telecommunications and Information Exchange between Systems Local and Metropolitan Area</i>	IEEE	2021

	<i>Networks--Specific Requirements Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications Amendment 1: Enhancements for High-Efficiency WLAN</i>		
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2.3 Definitions

The following terminology is used throughout this Technical Report.

CPE	Customer Premises Equipment. In the context of this Technical Report, CPE is used for any device or other equipment placed inside the premises of a Service Provider's customer.
Wi-Fi	A name created and trademarked by the Wi-Fi Alliance to describe technology based on IEEE 802.11 standards.
Dual-Band Mesh AP	AP Mesh system with one 2.4GHz radio and one 5GHz or 6GHz radio
Tri-Band Mesh AP	AP Mesh system with one 2.4GHz radio and at least two 5GHz or 6GHz radios

2.4 Abbreviations

This Technical Report uses the following abbreviations:

AVV	Attenuation Adjustment Value
AP	Access Point
DL	Downlink
DUT	Device Under Test
GE	Gigabit Ethernet
GUI	Graphical User Interface
IEEE	Institute of Electrical and Electronics Engineers
IP	Internet Protocol
IPv4	Internet Protocol version 4
LAN	Local Area Network
MAC	Medium Access Control
MCS	Modulation and Coding Scheme
MIMO	Multi-input Multi-output
MTU	Maximum Transmission Unit
MU-MIMO	Multi-user MIMO
NSS	Number of Spatial Streams
PC	Personal Computer
PER	Packet Error Rate
PHY	Physical Layer
QoS	Quality of Service
RCPI	Received Channel Power Indicator
RSSI	Received Signal Strength Indicator
RF	Radio Frequency
SSID	Service Set Identifier

STA	Station
TCP	Transmission Control Protocol
TR	Technical Report
Tx	Transmission
UL	Uplink
UDP	User Datagram Protocol
VLAN	Virtual Local Area Network
WA	Work Area
WLAN	Wireless Local Area Network
WMM	Wi-Fi Multimedia

3 Technical Report Impact

3.1 Energy Efficiency

TR-398 has no impact on Energy Efficiency.

3.2 Security

TR-398 has no impact on Security.

3.3 Privacy

Any issues regarding privacy are not affected by TR-398.

4 Equipment Features

4.1 Device Under Test (DUT) and Station (STA)

4.1.1 Device Information

Table 1 and Table 2 are intended to provide test engineers and readers of the test report with sufficient information about the DUT and connected STAs in order to assure repeatability of results and to allow for accurate comparisons of reported test results. The information defined in the tables SHALL be provided to the test engineer prior to the start of the testing and SHALL be included as part of the test report. All fields SHALL be populated; if an item is not applicable to the DUT or connected STAs, the item MAY be marked as “Not Applicable”.

Table 1: DUT Information

DUT system vendor	
DUT system firmware version	
DUT chipset vendor	
DUT chipset firmware version	

Table 2: STA Information

STA type (e.g., PC, mobile phone, etc.)	
STA system vendor	
STA system firmware version	
STA chipset vendor	
STA chipset firmware version	
Supported IEEE specification by STA	
Note: Multiple tables of STAs SHALL be created to record the information of STAs with different capability (e.g., legacy STA that supports only 802.11a/b/g).	

4.1.2 Management of the DUT and STA

The DUT SHALL support a DUT Northbound management protocol or local Graphical User Interface (GUI) that allows the ability to configure and retrieve the settings defined in 5.3 in this test plan. The management protocol is DUT vendor discretionary.

The STA SHALL support a STA Southbound management protocol that is required for execution of this test plan except as required to configure the STA to pass Ethernet traffic between the STA and Local Area Network (LAN) interface(s).

4.2 Testing Equipment and Components

This section includes tables to record information of testing equipment and components that are used in the test. The information defined in the tables SHALL be provided to the test engineer prior to the start of the testing and SHALL be included as part of the test report. All fields SHALL be populated; if an item is not applicable to the DUT or connected STAs, the item MAY be marked as “Not Applicable” .

Table 3: Traffic Generator/Analyzer Information

Manufacturer	
Equipment model	
Code version	

Table 4: Attenuator Information

Manufacturer	
Component model	
Supported frequency range	
Attenuation value used in the test	

Table 5: Test Chamber Information

Manufacturer	
Equipment model	

Table 6: Additional Antenna Information

Manufacturer	
Component model	
Where it is used (on test chamber/traffic analyzer/etc.)	

5 Test Environment

The Wi-Fi performance test environment can easily be impacted by external factors and the environment, such as existing office Wi-Fi systems, or nearby appliances (e.g., microwave ovens). The construction of the test environment used by this test plan SHALL be constructed in a fashion to mitigate the impact of these external factors. The test environment SHALL meet the requirements outlined in this section for all tests within this test plan.

5.1 Test Configuration

5.1.1 Ethernet/IP Traffic Setup

The LAN interface(s) used for transmission of test traffic SHALL be a Gigabit Ethernet port(s), supporting speeds of at least 1 Gbps. The Peer Stations (STAs) SHALL send/receive Wi-Fi packets to/from the DUT air interface or coax interface (if it is required). Packet generation, reception, and analysis SHALL be done using testing software or a traffic generator capable of generating stateful Transmission Control Protocol (TCP) and User Datagram Protocol (UDP) traffic with fixed (controlled) packet size.

The highest speed LAN port SHALL be used on the DUT when executing this test plan.

If the DUT supports Ethernet port with higher rate than 1Gbps (e.g., 2.5G, 5G, or 10G Ethernet, etc.), no additional port is used in the testing.

Figure 1 shows the basic setup for passing Ethernet/IP traffic through the DUT and single STA. Appendix I shows the instantiations of the test setups. The Packet Generator/Analyzer MAY be a discrete device from the STA, or the Packet Generator/Analyzer may be embedded directly on the STA device. The Packet Generator/Analyzer SHALL NOT be combined with the DUT and SHALL be a discrete device running the testing software to generate/receive the packets for DUT.

Note: The Physical Layer Test Setup shown in Figure 1 contains any specific test setup(s) or equipment that may be required within the Wi-Fi link, such as a channel simulator, attenuators, etc.

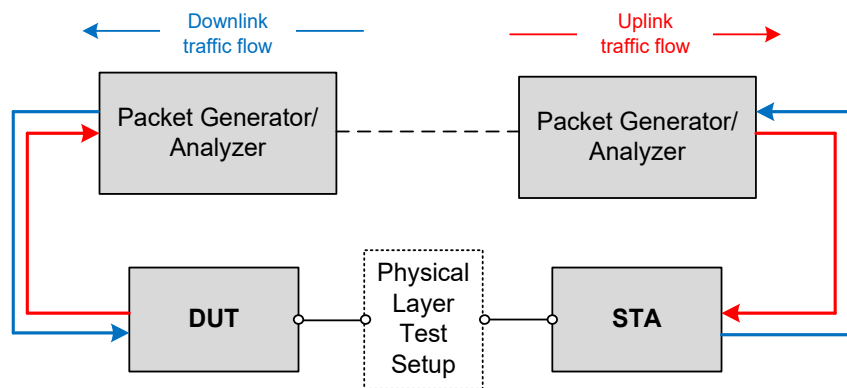


Figure 1: Test setup for performance testing for single STA

The DUT and STA SHOULD support the following requirements to enable these tests.

The DUT SHOULD support:

1. Forwarding of Ethernet/IP traffic between the Wi-Fi interface(s) and the LAN Ethernet interface, based on MAC learning or Virtual Local Area Network (VLAN) markings.
2. Allocating local IP address for STA through physical interface (air or cable) and for traffic generator.

The STA SHOULD support at least one of the following configurations:

1. In case the Packet Generator/Analyzer is used for STA, the interfaces between STA and Packet Generator/Analyzer SHALL fulfill the traffic flow requirement and not impact the performance test.

5.1.2 Ethernet Traffic Flow Generation

This section provides requirements for TCP and UDP settings in order to create consistent flow patterns while different testing software, operating systems or independent equipment are utilized in the test.

Where the Packet Generator/Analyzer is used to implement the traffic throughout measurements within this test plan, the following settings SHALL be used to configure the traffic generator. All throughput measurements SHALL be the layer 4 (payload rate) for the TCP or UDP traffic streams.

- Common setting for both TCP and UDP:
 - a) Establish TCP/UDP link through IP pairing before generation of traffic flow, i.e., setting up the IP address of DUT and STA to make sure that all of the devices are in the same LAN.
 - b) The flow generation SHALL be based on IPv4.
 - c) The test report SHALL include:
 - i. The name of the traffic tool with version number information
 - ii. The relevant settings for the type of traffic used. Even if the suggested settings described below are used, this information SHALL be included with the test report.
 - d) The TCP / DUP traffic settings SHALL be maintained consistently over all tests run as part of a single execution (i.e. a single test report) of this test plan, unless the settings are specifically altered in a test procedure for a given test case.
- Setting for TCP:
 - a) The following suggested setting SHOULD be used for TCP:
 - i. TCP window size SHOULD be set as 4MB.
 - ii. The number of parallel measurement streams SHOULD be set to 8.
 - b) The test tool SHALL create a stream of packets constructed of randomized bytes.
 - c) Each fragment of the file is sent continuously to the operating system running the test software.
 - d) TCP payload size SHOULD be determined by the operating system.
 - e) Unless otherwise specified in individual test cases, TCP traffic SHALL be configured to send at max possible rate.
- Setting for UDP:
 - a) The test tool SHALL create a stream of packets constructed of randomized bytes.
 - b) The following suggested settings SHOULD be used for UDP:
 - i. The UDP payload size SHOULD be set as 1472 bytes.
 - ii. The number of parallel measurements stream SHOULD be set to 1.

Note: A 1472 byte UDP data packet will lead to a 1500 byte IPv4 frame size. The UDP header is 8 bytes, and the IP header is 20 bytes, so this creates a 1500 byte packet which is where the 1500 byte MTU size limit is enforced. The resulting Ethernet frame will have an additional 14 bytes for the Ethernet header, and 4 bytes for the Ethernet CRC

5.1.3 Example: Ethernet traffic generation by iPerf3

Where the open source program iPerf3 is used to implement the traffic throughput measurements within this test plan, a predetermined set of command line flags SHALL be used to start and run the iPerf3 program as documented below, unless a specific test case provides alternate commands, to ensure consistency within testing.

The iPerf3 program runs as either a client or server process, where the server acts as a traffic reflector/recipient, while the client is responsible for the definition of specific tests/measurements to perform between the client and server processes. For the purposes of definitions below, the commands assume the iPerf3 server process is running on the AP side and the client process is running on the STA side of the Wi-Fi link. The client and server processes MAY be run on either side of the link during testing, provided the uplink/downlink definitions are consistently maintained.

The iPerf3 server SHALL be started with the command *iPerf3 --server*.

Specific client commands for each test scenario are located below. An explanation of the commands follows, for information only.

SERVER_IP address is the IP address of the system where the server is running.

TEST_TIME is the length of time the measurement will run for. This is set within each test case below.

The *bitrate* parameter is set to zero, to instruct iPerf3 to attempt to determine (measure) the maximum throughput between the client and server.

The *parallel* parameter instructs iPerf3 to run eight measurement streams in parallel between the client and server. This improves the overall accuracy of the measurement. The individual bandwidth used by each stream can vary, and the summation/average is used to calculate the overall measurement.

The *reverse* parameter instructs iPerf3 to measure the bandwidth from the server to the client. The default behaviour performs the measurement from the client to the server.

The *udp* parameter instructs iPerf3 to use the UDP transport instead of the default TCP transport.

The *omit 2* parameter instructs iPerf3 to “discard” the first 2 seconds of the measurement, to avoid inclusion of TCP slow start, etc.

Additional commands MAY be used to alter/direct logging or format of results, such as the *--logfile* or *--json* options. However, any additional command SHALL NOT alter the operation or measurement traffic used by the program.

The iPerf3 programs SHALL be run on a Linux based system, using a kernel version of 4.14 or newer. The system SHALL include at least one processor, with two cores, of at least 2 GHz.

5.1.3.1 Commands for iPerf3

The following unidirectional commands assume the iPerf3 client is running on the STA and measure the downlink throughput. To measure the uplink throughput the positions of the client and service processes could be reversed, or the *--reverse* flag could be omitted.

5.1.3.1.1 TCP Unidirectional Traffic Throughput Measurement

```
iPerf3 --client <SERVER_IP> --time <TEST_TIME> --bitrate 0 --parallel 8 --reverse --omit 2
```

5.1.3.1.2 UDP Unidirectional Traffic Throughput Measurement

```
iPerf3 --client <SERVER_IP> --time <TEST_TIME> --bitrate <BITRATE> --reverse --udp --omit 2
```

5.1.3.1.3 Bidirectional Traffic Throughput Measurements

For tests requiring bidirectional traffic throughput measurements, the --reverse flag is omitted and the --bidir flag is added. The change is applied to either the above TCP or UDP commands as needed.

5.2 Test Setup Characteristics

Test results obtained as a result of testing performed in accordance with TR-398 SHALL contain the information described in sections 5.2.1.

5.2.1 Shielded Test Chamber

Several tests specify an anechoic shielded chamber environment. Within this test environment, the ambient noise plus signal power, in the absence of the DUT and its Wi-Fi clients, SHALL be less than -100 dBm across the 80 MHz bandwidth at the working channel frequency, as measured by a spectrum analyzer with its resolution bandwidth set so it has the noise floor no more than -103dBm. This condition guarantees no false back off or contention take place and facilitates the correct performance measurement in extreme cases (e.g., performance testing with large attenuation).

5.2.1.1 Temperature and Humidity

The ranges of temperature and humidity of the test facility, over the entire time tests are conducted, SHALL be recorded as the high and low values observed during testing (see Table 7) and SHALL be included as part of the test report. The temperature SHOULD be within 21±5 °C. The relative humidity SHOULD be between 20% and 60%.

Table 7: Temperature and Humidity Range of Test Facility

Parameter	High	Low
Temperature		
Relative Humidity		

5.2.2 Distance and Test Channel Realization

To facilitate repeatable testing and support the application of absolute performance requirements, the wireless channel between the DUT and STA(s) needs to be well controlled. The test setup implemented SHALL meet the requirements within this section. Various methods to create and control this environment exist and MAY be used for the support of the testing defined in this document, provided the test setup implemented meets the requirements within sections.

The peer STAs are separated from the DUT by the Wi-Fi test channel. This separation can be defined as a specific distance, or as a specific path-loss. The test report SHALL indicate how the Wi-Fi test channel is established. The specific separation is defined in each test, however:

- a. If distance is used, then the peer STA SHALL be placed at the same height as the DUT. Additionally, the test report SHALL indicate the rotational orientation of both the STA and DUT. Both STA and DUT SHALL be placed in their “upright” position, as defined by the manufacturers.
- b. If external antenna is used, see section 5.2.4 Antenna Placement.
- c. If path-loss is used, then the peer STA SHALL be separated from the DUT such that the conditions of section 5.2.5 are met.
- d. A channel emulator (e.g., test equipment) MAY be used to implement the test channel.
- e. If the test channel is created using attenuators or a channel emulator, the test equipment SHALL support at least the same number of independent channels as the number of spatial streams being tested.
- f. The attenuators used to create signal attenuation SHALL perform flat attenuation in the frequency bandwidth.

There are several important parameters and conditions that define a test configuration. These are:

- The test environment SHALL be free from interference, and,
- There is a certain path loss between the devices, and,
- There is the ability to modify that path loss in a controllable and repeatable fashion.

There are several ways that such an environment could be implemented. A few possible options are shown below; either of these methods MAY be used to implement the testing defined within the document, or any other method could be used as long as it can be shown to meet the requirements of these sections. To simplify this document, each test case includes only a test setup figure or diagram based on the single chamber implementation.

Within a shielded chamber, RF signals will reflect from the chamber walls, and can appear as interference to the devices within the chamber. Any chamber used in the test plan SHOULD attenuate the reflections by at least 20 dB to minimize the impact of these reflections.

5.2.2.1 Single Chamber Implementation

In a single chamber implementation of the test environment, there is a single shielded chamber used to provide the interference-free environment, and physical separation is used to provide path-loss between devices. For path-loss modification, attenuators are placed on the STA antenna ports. Isolation of STA test device must be good enough that when attenuator is set to full attenuation, the STA cannot hear the DUT.

In this implementation, it is anticipated the single chamber provides the required shielding to meeting the ingress noise requirements. The chamber SHALL be large enough to meet the minimum RF insertion loss requirements defined in Section 5.2.5 and each test case.

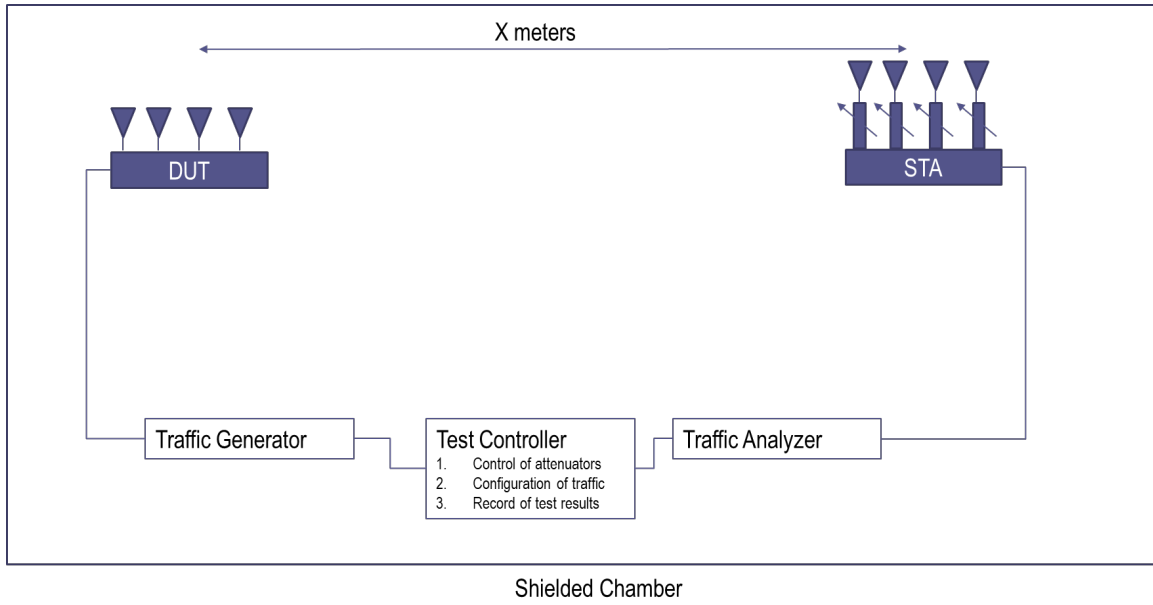


Figure 2: Single Chamber Implementation

5.2.2.2 Multiple Chamber Implementation

In a multiple chamber implementation of the test environment, there are multiple chambers used to provide the interference-free environment. The RF separation between the devices is composed of the free-space path-loss inside the chambers, the RF cabling that connects the boxes, and the variable attenuation. Additionally, a channel fader, or multi-path emulator, can also be inserted into the RF cable path to better align the test results with those observed in a purely free space environment. NOTE: The STA should be cabled directly to the 'probe ports' on the wall. The two over-the-air hops might not allow low enough insertion loss to meet the RF path loss requirements in section 5.2.5 of this test plan.

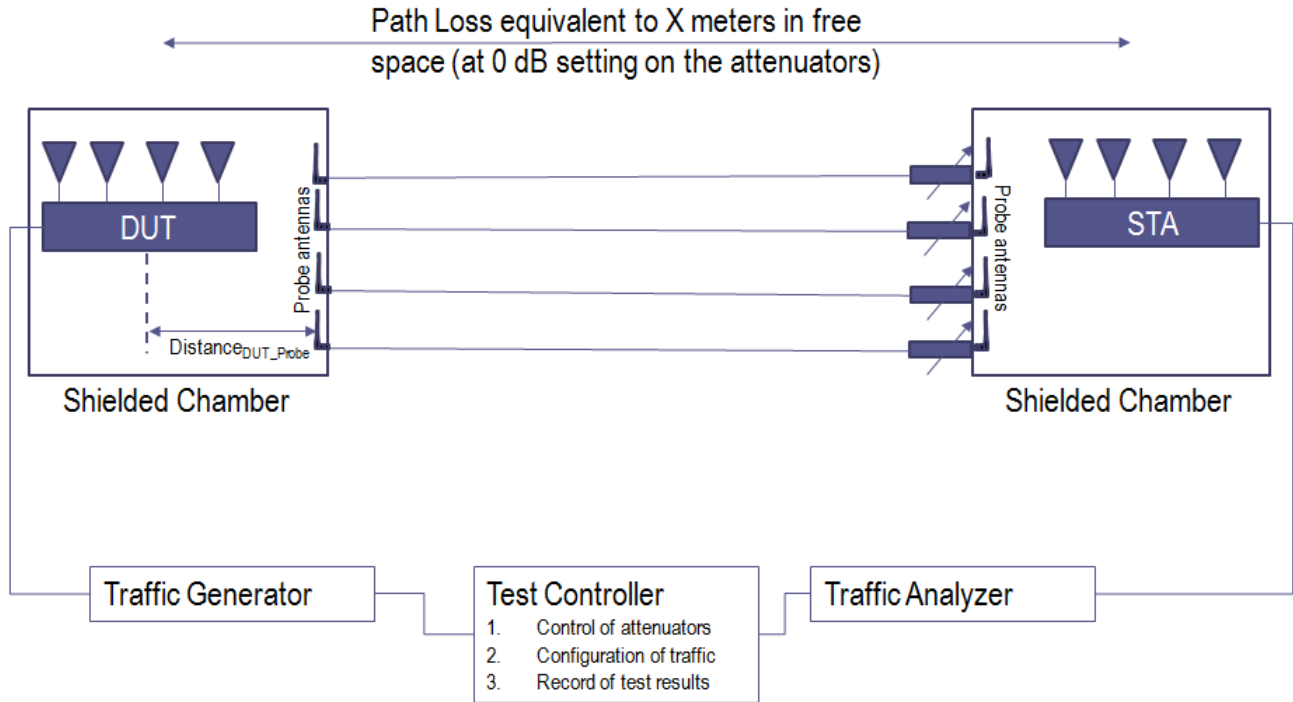


Figure 3: Multiple Chamber Implementation

5.2.2.3 Wi-Fi Mesh Multiple Chamber Implementation

This test environment is used to create a controlled RF path between 4 separate isolation chambers, as an expansion of the Multiple Chamber Implementation described above. In this test environment, the 4 isolation chambers are separated using 6 sets of attenuators (labeled as Attn A, Attn B, Attn C, Attn D, Attn E and Attn F). By configuring specific levels of attenuation for each set of attenuators, the test environment can be used to support testing of a multiple AP scenarios, where the STA might be connected to the “network” through a Wi-Fi extender placed in Chamber 2, or the STA could roam between a wireless network provided by DUT2 and DUT1, as the values of Attn C and Attn B are changed. Each test case utilizing this test environment SHALL include details of the required Attn configurations and changes.

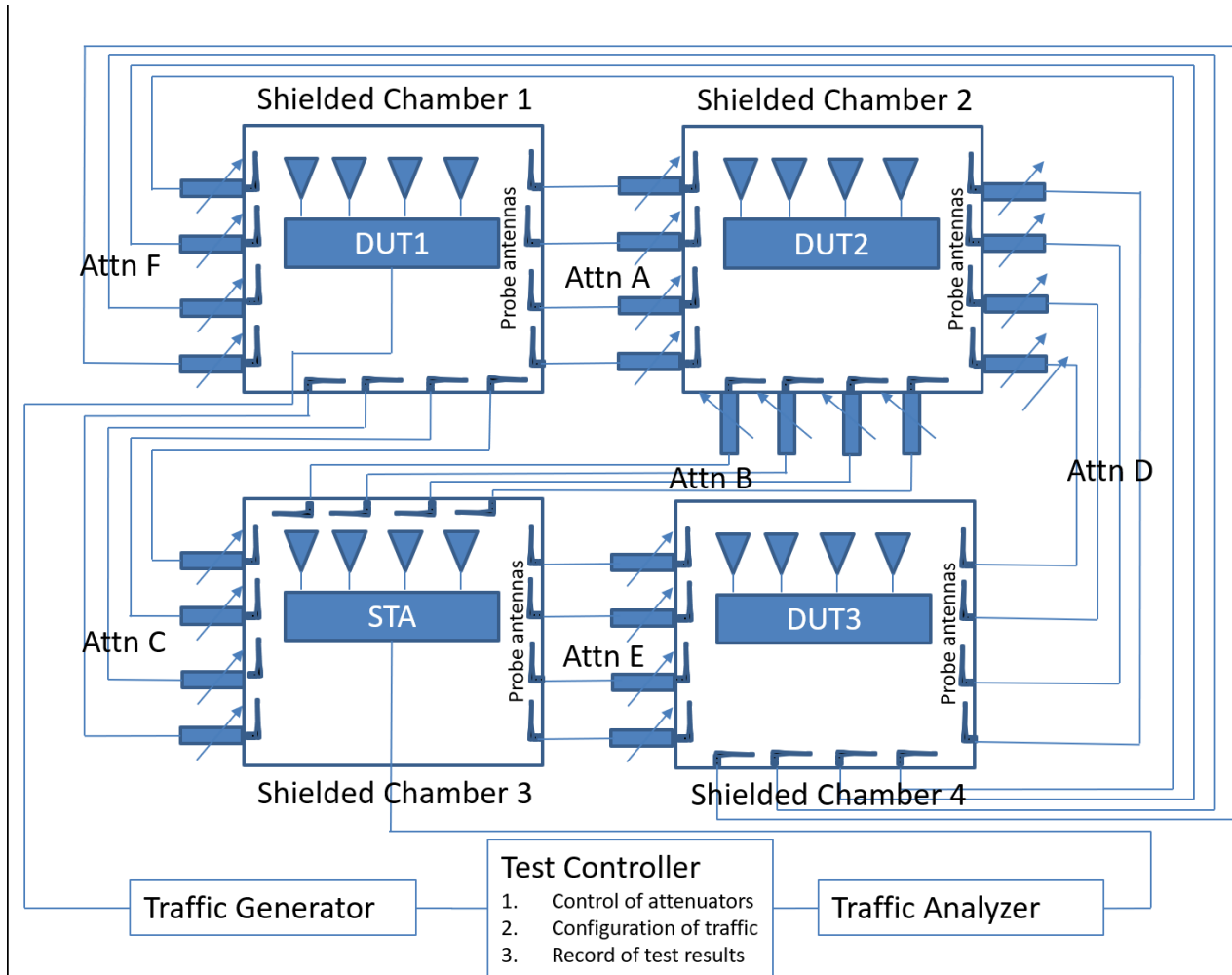


Figure 4: Wi-Fi Mesh Multiple Chamber Implementation

5.2.3 STA Requirements

The Wi-Fi Station (STA) acts as a peer device for transmitting and receiving data traffic from the Wi-Fi Access Point (DUT). The STA devices used for testing SHALL meet the requirements of this section.

The STA(s) SHALL support 2 spatial streams at 160 MHz in 6 GHz, 2 spatial streams at 80 MHz in 5 GHz and at least 2 spatial streams at 20 MHz in 2.4GHz.

The STA device(s) used for testing MAY be real products (i.e., a laptop or Phone) or MAY be dedicated test and measurement equipment that emulates the behavior of standard Wi-Fi station.

For tests that require multiple STA devices, the devices MAY be multiple discrete devices or the multiple STA devices may be emulated by a single test and measurement device.

Stations shall be configured for 2 spatial streams unless specified otherwise in the individual test cases.

Unless otherwise specified in individual tests, stations SHALL use, ignoring antenna gain, 20 dBm txpower on 2.4GHz band, 20 dBm txpower on 5GHz band and 14 dBm txpower on the 6 GHz band. If STA cannot

support the requested power, then attenuation may be decreased accordingly when running tests where the primary traffic flow is STA to DUT. Certain tests may request different STA txpower.

Antennas used by STA are assumed to have similar gain in TX and RX direction.

5.2.4 Antenna Placement

To have consistent results across different testbeds the following approach to antenna placement SHALL be followed. Figure 5 below shows the inside of the wireless isolation chamber during testing, from the top and front side view of the chamber. Note, the angles are not to scale and are expanded / exaggerated to accommodate labels and text.

Top View #1 shows the relationship between the antennas of the STA1 and the DUT. The STA1 is the test device used to implement any test case requiring only one STA device, or one set of virtual (emulated) STA devices at the same attenuation “distance” from the DUT. In this view, the “front” of the DUT is indicated by the thicker black line. The front of the DUT SHALL be clearly marked by the supplier prior to the start of testing, or SHALL be considered as the side of the device opposite (180 degrees) of the device’s power connection. In this configuration, the rotational angle of the DUT is “set” to zero.

The Side View (front) shows the relationship between the antennas and the DUT, relative to the antenna mounting height in the isolation chamber. In this figure, Θ_4 is angle between the two antennas, where ideally, this angle would be zero, if all antennas are mounted at the same height within the test chamber.

The Aiming Point of the antennas, as shown by the \diamond in Figure 1 SHALL be either:

- 1) The center of mass of the DUT, or
- 2) The center of the antennas, as defined and documented by the DUT supplier prior to the start of testing.

The angle of each antenna SHALL meet the following requirements:

- $0 \leq \Theta_1 \leq 45$
- $0 \leq \Theta_2 \leq 45$
- $0 \leq \Theta_3 \leq 45$
- $\Theta_4 \leq 10$

The above requirements MAY be extended to allow for 3 or 4 antennas associated with a STA, by treating the above requirements as the maximum for the set of antennas.

The distance of each antenna, relative to the Aiming Point of the DUT, SHALL meet the following requirements:

- $25 \leq d_1 \leq 60$

No antenna may be located closer than 4 cm to another antenna.

Additionally, care should be taken to avoid placing antennas at multiples of the wavelengths, 12.5, 5.2, or 5 cm for 2.4, 5, or 6 GHz respectively.

The above requirements SHALL be repeated for each set of STA antennas (STA2 & STA3) required for testing, assuming a base incident angle to the DUT of 90 or 180 degrees, as shown in Top View #2.

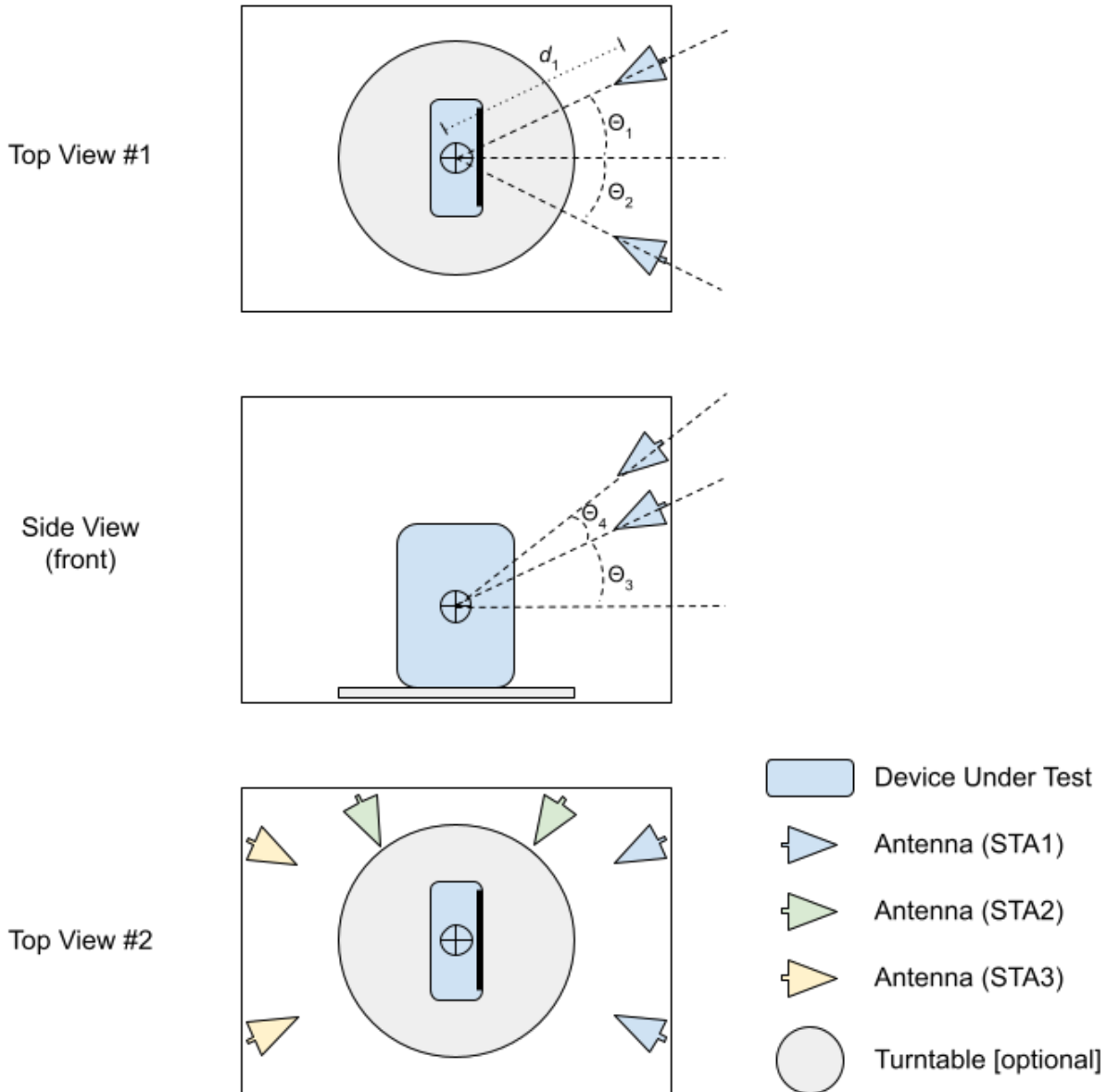


Figure 5: Antenna Locations relative to the Aiming Point

For all types of DUT (External Antennas, Integrated Antennas for ceiling or wall mount and Integrated Antenna towers), the antennas SHALL be pointing at the center of mass of the DUT. Ceiling mount DUTs SHALL be placed flat in the testbed facing up. Wall-mount DUTs may require a vendor supplied stand to keep them upright.

5.2.5 Calibration and tuning of the Wi-Fi Test Channel

The following steps describe a process that should be used to adjust the attenuation values used in each test case within this test plan. The outcome of the process below is an attenuation adjustment value (AAV) for the 2.4GHz and 5GHz bands that should be added to each attenuation value used within this test plan. The following rules shall be used when applying the AAV to test cases:

- Single band 2.4 GHz test cases use the 2.4 GHz AAV calibration value.

- Single band 5GHz and 6 GHz test cases use the 5 GHz AAV calibration value.
- All dual band and multiband test cases use the 5 GHz AAV calibration value.

For example, if a test case requires the attenuator be set to 10 dB, using the 2.4GHz band only and the value of AAV for 2.4 GHz is determined to be 2 dB, the attenuator value used during testing would be 12 dB. It is expected in dual/multi band testing that the value determined using the 5 GHz band will result in slightly higher power levels being received when using the 2.4 GHz bands. However, the IEEE 802.11 specifications account for this, in additional allowances for the 2.4 GHz band.

The AAV determined by the process described in this section could be less than zero. This case indicates the test setup being considered is not able to implement the requirements within this test plan.

Other methods to determine the AAV also exist and could be used, such as measurement of the test setup using equipment such as network analyzers or other test and measurement devices.

To measure the AAV, a single, dipole antenna SHALL be used. The center of that dipole antenna SHALL be positioned to the center of the test chamber volume. The antenna MUST be omnidirectional on the horizontal plane (i.e., the plane the DUT will rotate on in the spatial consistency test case within this test plan). This antenna SHALL be fed from an AP device configured for 1 spatial stream and with a known transmit power at the connection point of the AP to the antenna. The AP is referred to as AP_ref. The AP TX power value SHALL be referred to as Tx_AP_actual_, where Tx_AP_actual is in units of dBm.

Define these variables:

- For 2.4 GHz bands:
 - Target_RSSI = -25 dBm (Note 1)
 - TxAP_Ideal = 30 dBm (Note 2 & 3)
- For 5 GHz bands:
 - Target_RSSI = -30 dBm (Note 1)
 - TxAP_Ideal = 30 dBm (Note 2 & 3)

Notes:

1. The expected RSSI for the 2.4 and 5 GHz bands are based on reduction of the maximum allowed received power, as defined within the 803.11 specification for the 802.11ax operation mode, refer to 802.11 section 27.3.20.5.
2. The maximum allowed transmission power in the 2.4 and 5 GHz bands within the USA regulatory domain is +30 dBm (1W), per FCC rules 15.247 and 15.407 respectively.
3. If the DUT transmits with a Tx Power above this value, it may be necessary to increase the value of AAV test cases or test points where the additional attenuation is less than 10 dB. Adjustments to the applied AAV value should be noted in the test report.

For each test channel within the test setup, the following procedure is performed. This procedure MUST be repeated for each set of STA and attenuators within the test setup.

1. Set the attenuator directly within the test channel to 0 dB. For test setups with multiple paths, all other attenuators are set to their maximum value.
2. Configure the AP_ref to operational mode: 802.11ac, 20 MHz, NSS = 1.
3. Configure the STA to associate with the AP_ref.
4. Configure the traffic generator to run a downstream TCP throughput test for 60 seconds.
5. After the traffic has run for 30 seconds, record the reported RSSI (received signal strength indicator) reported by the STA, as RSSI and RSSI_x is expressed in units of dBm. Refer to Note 1 for additional details.
6. Calculate the AAV_i using the following equation, where i indicates the attenuation step being measured and Attn is the attenuation value set within the test channel.
 - a. $AAV_i = (RSSI - Target_RSSI) - (TxAP_actual - TxAP_Ideal) - G_antenna + Attn$

7. Repeat steps 1 through 6 for the following attenuation settings, 10 db, 20 db, 30 dB.
8. Calculate the value of AAV_x as the average of the AAV_x_i values recorded above, where x is an indicator of the applicable band (2.4 GHz or 5 GHz).
9. Repeat steps 3 through 8 for an operational mode of 802.11n, 20 MHz, NSS-1.
10. Repeat the above steps for each STA and attenuator pair used within the test setup.

Note 1: The RSSI value used MUST be either the value reported by a single receiver / antenna, or the average of the values reported per receiver / antenna in the case of a STA supporting antenna diversity. Care must be taken to ensure the value used from STA supporting antenna diversity is not measured from a power summation over multiple receivers / antennas, because that value will be artificially high compared to the single RF path value.

To confirm the outcome of the calibration process above, the procedure may be repeated, adding the value of AAV_x to the attenuation setting applied to the test channel. The observed absolute value of AAV_i for each attenuation step (Attn) should be less than or equal to 3 dB.

5.2.6 Definition of close, medium, and far station distances

Several test cases in this test plan use the wording of close, medium, and far station distances. The table below defines these distances for the attenuation values.

Table 8: Definition of close, medium, and far station distances

Band	Close (dB)	Medium (dB)	Far (dB)
2.4 GHz	12	30	43
5 GHz	6	24	39
6 GHz	0	15	27

Note: All values above will be offset by the AAV produced during calibration defined in section 5.2.5
 Note: In test cases where dual band or multiband testing takes place the 5 GHz values SHALL be used.
 Note: Close / Medium / Far values are aiming for an approximate target RSSI of -45 / -60 / -75 for the AP with +23 txpower on 2.4/5 GHz bands and +14 txpower for 6 GHz

5.3 Device Under Test (DUT) settings

5.3.1 DUT Requirements

The DUT SHALL be able to support at least 2 spatial streams (NSS≥2 as defined in the 802.11n/ac/ax specification) for Wi-Fi packet transmission.

The test report SHALL document the channel used in the test plan. If the channel is not supported due to regulatory issue, a neighbor channel SHALL be selected accordingly. The peer STA/STAs register to the DUT to establish the link.

Note: A fixed channel facilitates good repeatability across the tests in labs.

DUT SHALL NOT use any proprietary implementation beyond the scope of Wi-Fi standard [1], e.g., 256QAM modulation for 802.11n, etc.

If the DUT only has LAN ports supporting a certain interface speed, performance tests will be limited by the LAN port speed and the maximum pass/fail criteria will be the values in Table 9 for the LAN interface on DUT. The highest speed DUT LAN interface SHALL be used in testing.

Table 9: Maximum Pass/Fail Criteria based on supported DUT LAN port

Maximum LAN Port Speed on DUT	Maximum Pass/Fail Criteria
1 Gbps	925 Mbps
2.5 Gbps	2,312 Mbps
5 Gbps	4,625 Mbps
10 Gbps	9,250 Mbps

5.3.2 SSID settings

The setting for Service Set Identifier (SSID) SHALL be configured as defined in Table 10. SSID for 2.4 GHz and 5 GHz band SHALL be set up separately. The DUT SHALL be configured to enable only one SSID per band during all testing, to prevent any performance degradation caused by the broadcast of the additional SSID. For example, some devices may support a “Guest” Wi-Fi network, where this SSID / network needs to be disabled during the testing.

Table 10: SSID setting configuration

Configuration Parameters	Default value
SSID name	BBF Wi-Fi Perf Test XG (NOTE1)
Enable SSID	True
Number of associated devices	32
Broadcast SSID	True
Enable WMM	True
Authentication Mode	WPA3-Personal (Note 3)
Encryption Mode	AES
WPA PreSharedKey	(NOTE2)
WPA Group Key Regeneration Interval	3600 seconds
<p>Note 1: “X” represents “2.4” when DUT is configured to work in 2.4 GHz band while “X” represents “5” when DUT is configured to work in 5 GHz band. X” represents “6” when DUT is configured in 6 GHz.</p> <p>Note 2: Defined by test agent.</p> <p>Note 3: WPA2-Personal for older DUTs</p>	

5.3.3 Radio interface settings

Wi-Fi systems are required to conform to various regulatory requirements, based on the region of the world in which the system is currently operating. One component to these requirements is typically the definition of the maximum allowed transmit power (Tx Power). Changes to the transmit power used by the DUT can have an impact on the testing results within this test plan.

The DUT SHALL be set to maximum power suggested by the AP manufacturer.

In general, only one operating band/mode is tested at a time, such as 802.11n on 2.4 GHz or 802.11ax on 5 GHz. To ensure the desired band/mode is being tested, the STA SHOULD support a configuration mechanism to connect only in the desired band. If the STA does not support this configuration mechanism, only the band/mode being tested SHALL be enabled on the DUT and all other bands/modes supported by the DUT SHALL be disabled, unless otherwise directed within a specific test case.

5.3.3.1 802.11n Configuration

All the DUT supporting 802.11n SHALL set the operating frequency band as 2.4 GHz. The default setting SHALL be configured as defined in Table 11.

Table 11: Work setting configuration for 802.11n 2.4 GHz band

Configuration Parameters	Default value
Tx Power	100 %
Regulatory Domain	(NOTE 1)
Channel	Channel 6
Chanel Width	20 MHz
Standard mode	802.11n (NOTE 2)
Note 1: Defined by test agent or automatically selected by the DUT.	
Note 2: If the DUT does not support control over the enabled standard, the STA SHALL be configured to only enable 802.11n.	

All of the test cases in this test plan for 802.11n SHALL be conducted in the working frequency of 2.4 GHz.

5.3.3.2 802.11ac Configuration

All the DUT supporting 802.11ac SHALL set the operating frequency band as 5 GHz. The default setting for work mode SHALL be configured as defined in Table 12.

Table 12: Work setting configuration for 802.11ac 5 GHz band

Configuration Parameters	Default value
Tx Power	100 %
Regulatory Domain	(NOTE 1)
Channel	Channel 36
Chanel Width	20/40/80 MHz
Standard mode	802.11ac (NOTE 2)

Note 1: defined by test agent or automatically selected by the DUT.

Note 2: If the DUT does not support control over the enabled standard, the STA SHALL be configured to only enable 802.11ac.

5.3.3.3 802.11ax Configuration

All the DUT supporting 802.11ax SHALL set the operating frequency band as either 2.4 GHz or 5 GHz or 6 GHz. All supported bands SHALL be tested. The default setting for work mode SHALL be configured as defined in Table 13.

Table 13: Work setting configuration for 802.11ax (2.4, 5 & 6 GHz band)

Configuration Parameters	Default value
Tx Power	100 %
Regulatory Domain	(NOTE 1)
Channel (NOTE 2)	Channel 6 (2437 MHz) or 36 (5180 MHz) or 47 (6185 MHz)
Chanel Width	20 MHz for 2.4 GHz 20/40/80 MHz for 5 GHz 80/160 MHz for 6 GHz
Standard mode	802.11ax
<p>Note 1: Defined by test agent or automatically selected by the DUT.</p> <p>Note 2: Channel 6 SHALL be used for 2.4 GHz testing, Channel 36 SHALL be used for 5 GHz testing. Channel 47 SHALL be used for 6 GHz testing.</p>	

6 Performance Tests

Chapter 6 includes a set of test cases for verification of Wi-Fi performance. Test cases are categorized into 5 sets (RF capability, Baseline performance, Coverage, Multiple STAs performance, and Stability/Robustness).

6.1 RF capability

6.1.1 Receiver Sensitivity Test

6.1.1.1 Introduction

Receiver Sensitivity is a receiver's ability to receive and correctly demodulate weak signals. This test provides a simplified measurement of the receiver's sensitivity, relative to the total attenuation inserted between the DUT and the STA. As that attenuation is increased, the STA is limited to a single MCS, eventually causing the connection to degrade. The point at which the connection degrades represents the receiver's approximate sensitivity. This is an approximate measurement only, where a detailed receiver sensitivity measurement would typically be performed in a conducted test environment with calibrated transmitter power levels. The test is repeated with multiple MCSs, ensuring the DUT should smoothly transition between MCSs as the attenuation increases in normal operation.

This test SHALL be OPTIONAL for the test plan.

6.1.1.2 Setup

1. The test setup (shown in Figure 6) SHALL utilize a shielded chamber (see section 5.2.1 and 5.2.2).
2. A Traffic Generator/Analyzer is connected to the station and DUT, capable of sending and receiving Ethernet frames in order to measure packet error rate. A UDP link SHALL be established between DUT and STA and traffic rate SHALL be set to 65% of the theoretical maximum throughput rate for each Modulation and Coding Scheme (MCS). The direction of data packet is from STA to DUT.
3. A controllable attenuator is added to each RF path between the STA and DUT. The attenuator SHALL support the attenuation values between 0 dB and 60 dB, in 1 dB steps. All attenuation values specified in this test case assume that 0 attenuation is based on the calibration done in section 5.2.5.
4. A rotation platform is used to rotate the DUT for angle-based data collection.
5. The STA TX power SHALL be set to 10 dBm all bands being tested.
6. The STA must be configured to send at a specific MCS, NSS, and bandwidth.

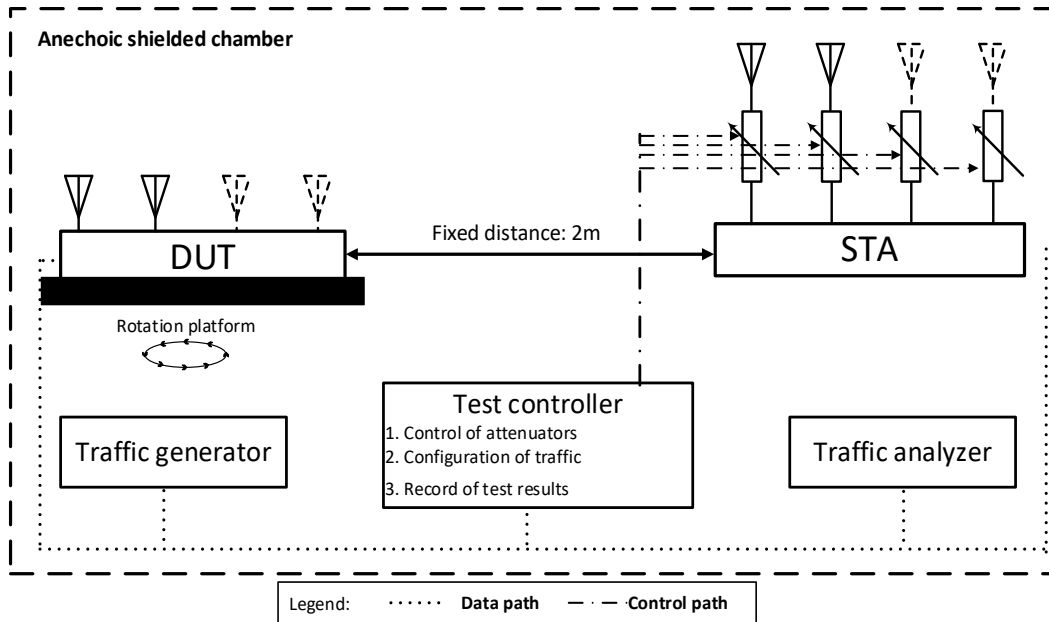


Figure 6: Test Setup for Receiver Sensitivity

6.1.1.3 DUT Configuration

The test SHALL be run using the each of the configurations from Table 14 below supported by the DUT. The test SHALL be conducted to the configurations that the DUT supports.

Table 14: Wi-Fi Test Configurations for Receiver Sensitivity

Test Configuration	Wi-Fi configuration
1	802.11n/2.4 GHz/20 MHz
2	802.11ac/80 MHz
3	802.11ax / 2.4 GHz / 20 MHz
4	802.11ax / 5 GHz / 80 MHz
NOTE: Both configurations SHALL use a station supporting one spatial stream (NSS =1) only.	

Note: The test plan considers the common configurations to reduce the testing complexity.

6.1.1.4 Procedure

1. Set the rotation angle to 0 degree.
2. Configure the STA to use the MCS rate for the first test index from Table 15, Table 16, Table 17, or Table 18 applicable to the test configuration from Table 14.
3. Configure the Traffic Generator to use the test data rate from Table 15, Table 16, Table 17, or Table 18 for the configured MCS rate.
4. The STA adaptive rate-control (MCS, bandwidth, spatial streams adjustments) must be disabled so that exactly the requested MCS/NSS/bandwidth is used for the data packets used to calculate the pass/fail metrics.
5. Allow STA to associate with the DUT.
6. Configure the attenuator(s) to 5 dB less than the pass/fail cutoff for the configured MCS rate.

7. Enable packet generation from the STA to the DUT for 20 seconds.
8. Record packet error rate (PER) of the UDP traffic stream.
9. Increase the attenuator by 1 dB and repeat steps 6-8 until the PER is greater than 10%. Record the final passing attenuation value as the approximate receiver sensitivity.
10. Increase the rotation angle by 45 degrees. Repeat Step 5 through 8 until the DUT has been rotated by 360 degrees. Calculate the average receiver sensitivity.
11. Repeat steps 1 through 9 for each test index from Table 15, Table 16, Table 17, or Table 18 applicable to each test configuration from Table 14.
12. Repeat steps 1 through 10 for each test configuration in Table 14 supported by the DUT.

Table 15: MCS and Traffic Test Configuration for 802.11n

Test Index	MCS Index	Modulation	Data Rates (Mbps) GI = 800 ns	
			20 MHz channel, NSS = 1	
			Theoretical	Test Configuration
1	0	BPSK	6.5	4.23
2	7	64-QAM	65	42.25
Note 1: The MCS rates are defined in Ref [3]. Note 2: Data rates specified for Long Guard interval, while testing may be performed using either guard interval, as supported by the DUT.				

Table 16: MCS and Traffic Test Configuration for 802.11ac

Test Index	MCS Index	Modulation	Data Rates (Mbps) GI = 800 ns	
			80 MHz channel, NSS = 1	
			Theoretical	Test Configuration
3	0	BPSK	29.3	19.05
4	9	256-QAM	390	253.5
Note 1: The MCS rates are defined in Ref [3]. Note 2: Data rates specified for Long Guard interval, while testing may be performed using either guard interval, as supported by the DUT.				

Table 17: MCS and Traffic Test Configuration for 802.11ax 2.4 GHz

Test Index	MCS Index	Modulation	Data Rates (Mbps) GI = 1600 ns	
			20 MHz channel, NSS = 1	
			Theoretical	Test Configuration
5	0	BPSK	8	5.2
6	11	1024-QAM	135	87.75
Note 1: The MCS rates are defined in Ref [3]. Note 2: Data rates specified for Long Guard interval, while testing may be performed using either guard interval, as supported by the DUT.				

Table 18: MCS and Traffic Test Configuration for 802.11ax 5 GHz

Test Index	MCS Index	Modulation	Data Rates (Mbps) GI = 1600 ns	
			80 MHz channel, NSS = 1	
			Theoretical	Test Configuration
7	0	BPSK	34	22.1
8	11	1024-QAM	567	374.4

Note 1: The MCS rates are defined in Ref [3].
Note 2: Data rates specified for Long Guard interval, while testing may be performed using either guard interval, as supported by the DUT.

6.1.1.5 Metrics (Pass/Fail Criteria)

1. The measured average (between all rotation points) receiver sensitivity (inserted attenuation) in the test SHALL be greater than or equal to the required receiver sensitivity, as shown in Table 19 ,Table 20, Table 21 and Table 22.
2. For each set of results, if there are more than 2 samples that are less than 4db below passing value for the averages specified in section 1, the test result for that MCS is considered failed.

Table 19: Required Receiver Sensitivity for 802.11n

Test Index	MCS Index	Modulation	Approximate Receiver Sensitivity (dB)
			Required (NSS=1)
1	0	BPSK	49
2	7	64-QAM	31

Table 20: Required Receiver Sensitivity for 802.11ac

Test Index	MCS Index	Modulation	Approximate Receiver Sensitivity (dB)
			Required (NSS=1)
3	0	BPSK	39
4	9	256-QAM	14

Table 21: Required Receiver Sensitivity for 802.11ax 2.4 GHz

Test Index	MCS Index	Modulation	Approximate Receiver Sensitivity (dB)
			Required (NSS=1)
5	0	BPSK	49
6	11	1024-QAM	26

Table 22: Required Receiver Sensitivity for 802.11ax 5 GHz

Test Index	MCS Index	Modulation	Approximate Receiver Sensitivity (dB)
			Required (NSS=1)
7	0	BPSK	39
8	11	1024-QAM	14

6.2 Baseline performance

6.2.1 Maximum Connection Test

6.2.1.1 Introduction

The Maximum Connection test intends to verify that the Wi-Fi AP can support 32 STAs simultaneously connected with minimal packet loss and no disassociations taking place.

This test SHALL be MANDATORY for the test plan.

6.2.1.2 Setup

1. The test setup (shown in Figure 7) SHALL be located in anechoic shielded chamber (see section 5.2.1 and 5.2.2).
2. A Traffic Generator/Analyzer, sending the Ethernet packets, connects to the LAN interface (e.g., GE port) of the DUT.
3. The peer STAs and DUT are placed at the AAV as calibrated in section 5.2.5 based on the profile under test.
4. 32 STAs are prepared and associated to DUT during the test.
5. UDP connection SHALL be used for Ethernet packet transmission in the test.
6. STAs shall be configured to use 2 spatial streams.

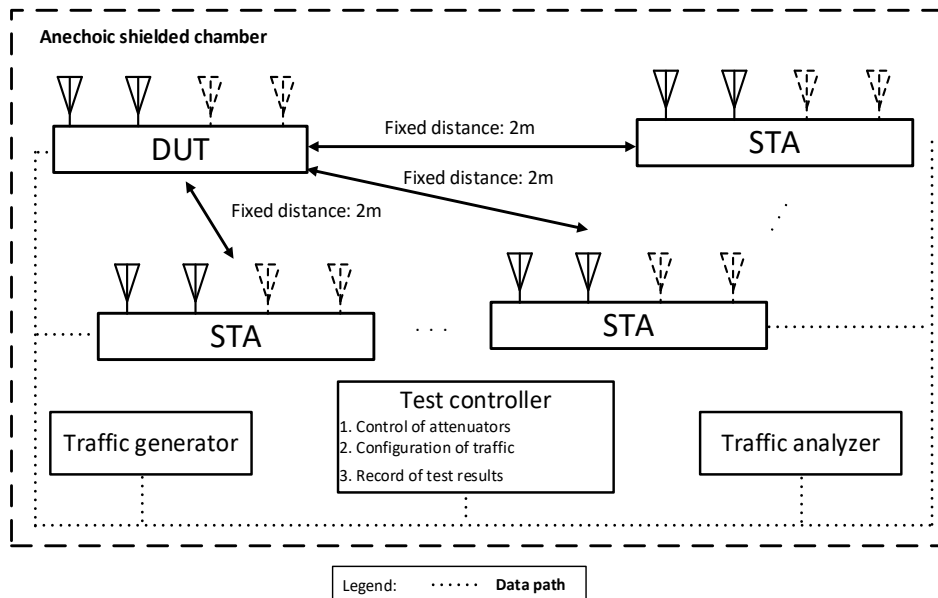


Figure 7: Test setup of Maximum Connection Test

Note: The test result may be slightly affected by the capability of Peer STA. It is recommended STA used in the test have chipsets from at least 2 different vendors.

6.2.1.3 DUT Configuration

The test SHALL run under the following configuration:

1. The DUT shall be configured for different modes:
 - a) 802.11n
 - b) 802.11ac
 - c) 802.11ax over 2.4 GHz
 - d) 802.11ax over 5 GHz
 - e) 802.11ax over 6 GHz

6.2.1.4 Procedures

1. Configure the operating mode of the DUT to the first supported configuration listed above.
2. Allow the STA to associate with the DUT.
3. Simultaneously measure the downlink UDP packet loss, using a test time of 120 seconds and a traffic rate of 2 Mbps for 802.11n, 8 Mbps for 802.11ac, 3 Mbps for 802.11ax over 2.4 GHz, 10 Mbps for 802.11ax over 5 GHz, or 10 Mbps for 802.11ax over 6 GHz, through each STA. Record the number of packets transmitted and received to calculate the packet error rate.
4. Simultaneously measure the uplink UDP packet loss, using a test time of 120 seconds and a traffic rate of 2 Mbps for 802.11n or 8 Mbps for 802.11ac, 3 Mbps for 802.11ax over 2.4 GHz, 10 Mbps for 802.11ax over 5 GHz, or 10 Mbps for 802.11ax over 6 GHz through each STA. Record the number of packets transmitted and received to calculate the packet error rate.
5. Repeat steps 2 through 4 for each additional configuration / operating mode supported by the DUT.

6.2.1.5 Metrics (Pass/Fail Criteria)

In order to pass the test case, the recorded results SHALL meet the Pass/Fail Criteria, described as following:

1. For each of the test configurations, Packet Error Rate (PER) for each STA SHALL achieve less than 1 %.
2. For each of the test configuration, the overall throughput of all connected STA SHALL achieve:
 - a) For 32 connected STA (802.11n), both downlink and uplink summed throughput SHALL be not less than 64 Mbps * 99%.
 - b) For 32 connected STA (802.11ac), both downlink and uplink summed throughput SHALL be not less than 256 Mbps * 99%.
 - c) For 32 connected STA (802.11ax over 2.4 GHz), both downlink and uplink summed throughput SHALL be not less than 96 Mbps * 99%.
 - d) For 32 connected STA (802.11ax over 5 GHz), both downlink and uplink summed throughput SHALL be not less than 320 Mbps * 99%.
 - e) For 32 connected STA (802.11ax over 6GHz), both downlink and uplink summed throughput SHALL be not less than 320 Mbps * 99%.

6.2.2 Maximum Throughput Test

6.2.2.1 Introduction

Maximum throughput test intends to measure the maximum throughput performance of the DUT. The test is conducted with connection by air interface in short distance (by considering the actual utilization of Wi-Fi).

This test SHALL be MANDATORY for the test plan.

6.2.2.2 Setup

1. The test setup (shown in Figure 8) SHALL be located in the anechoic shielded chamber (see section 5.2.1 and 5.2.2).
2. A Traffic Generator/Analyzer, sending the Ethernet packets, connects to the LAN interface (e.g., GE port) of the DUT.
3. The peer STA and DUT are placed at the AAV as calibrated in section 5.2.5 based on the profile under test.
4. TCP connection SHALL be used for Ethernet packet transmission in the test.
5. STA shall be configured to use 2 spatial steams.

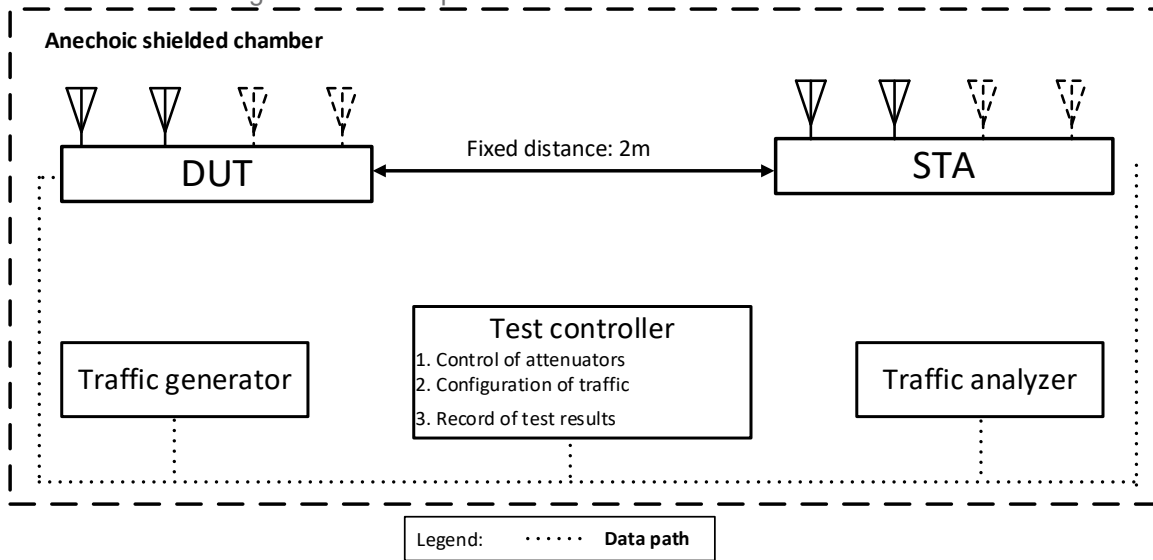


Figure 8: Test setup of Maximum Throughput Test

6.2.2.3 DUT configuration

The test SHALL run under the following configuration:

1. The DUT shall be configured for different modes:
 - a) 802.11n
 - b) 802.11ac
 - c) 802.11ax over 2.4 GHz
 - d) 802.11ax over 5 GHz
 - e) 802.11ax over 6 GHz

The test case SHALL be conducted on all the applicable modes of the DUT.

6.2.2.4 Procedures

1. Configure the working mode of DUT to 802.11n with default configuration.
2. Establish the LAN connection and allow the STA to associate with the DUT.
3. Measure the downlink TCP throughput to the STA, using a test time of 120 seconds.
4. Measure the uplink TCP throughput to the STA, using a test time of 120 seconds.
5. Set the working mode of DUT to 802.11ac, and repeat steps 3-4.
6. Set the working mode of DUT to 802.11ax over 2.4 GHz, and repeat steps 3-4.
7. Set the working mode of DUT to 802.11ax over 5 GHz, and repeat steps 3-4.
8. Set the working mode of DUT to 802.11ax over 6 GHz, and repeat steps 3-4.

Note: The test result MAY be slightly affected by the capability of peer STA. The test can be conducted with different peer STAs with chipsets from different vendors. The calculated average throughput then can be averaged again in the dimension of chipset.

6.2.2.5 Metrics (Pass/Fail Criteria)

In order to pass the test case, the recorded results SHALL meet the Pass/Fail Criteria, described as following:

1. The measured average throughput SHALL meet the performance requirement of Table 23.

Table 23: The Throughput Requirement

Wi-Fi configuration (DUT)	Wi-Fi configuration (Peer STA)	Bandwidth (MHz)	Downlink throughput requirement (Mbps)	Uplink throughput requirement (Mbps)
802.11n (NSS=2)	802.11n (NSS=2)	20	100	100
802.11ac (NSS=2)	802.11ac (NSS=2)	80	650	650
802.11ax (2.4 GHz, NSS=2)	802.11ax (2.4 GHz, NSS=2)	20	180	180
802.11ax (5 GHz, NSS=2)	802.11ax (5 GHz, NSS=2)	80	880	880
802.11ax (6 GHz, NSS=2)	802.11ax (6 GHz, NSS=2)	160	1500	1500
<p>Note: Maximum Pass/Fail Criteria will be restricted by the values found in Table 9 based on the DUT LAN port speed</p>				

6.2.3 Airtime Fairness Test

6.2.3.1 Introduction

Wi-Fi signal transmission can be seen as a multicast process since the STAs involved share the transmission medium. Air interface becomes a rare resource when dense connections or high throughput requests exist. Channel condition determines the MCS selection, therefore affecting the data throughput. In general, long distance to travel or obstacle penetration leads to larger attenuation, which makes the data rate in a low level. Occupying excessive airtime of STA with small MCS will be unfair to the STAs with large MCS (here, assuming the QoS requirement is similar) when the air resources have already run out.

Airtime Fairness Test intends to verify the capability of Wi-Fi device to guarantee the fairness of airtime usage. This test uses two stations at a time, with one station running in optimum configuration. The second station varies between optimum configuration, weaker signal, and legacy mode configurations. In each setting, TCP traffic is used to determine maximum capacity of each station running by itself. Then, UDP traffic is created on STA1 to run at 75% of the TCP throughput and UDP traffic is created on the second station at 50% of the TCP throughput for that station. This overdrives the AP and causes it to drop frames. The pass/fail criteria are that each station gets at least 45% of the TCP throughput when both stations are running the prescribed UDP traffic.

This test SHALL be MANDATORY for the test plan.

6.2.3.2 Setup

1. The test setup (shown in Figure 9) SHALL be located in the anechoic shielded chamber (see section 5.2.1 and 5.2.2).
2. Three peer STAs are used in the test. STA1 and STA2 are 802.11n/ac/ax devices with the same number of spatial streams supported by the DUT in both 2.4 and 5 GHz bands. STA3 is a legacy 802.11a/b/g, 802.11n NSS = 1, or 802.11ac NSS = 1 device, depending on the operating mode under test.
3. All STAs and DUT are placed at the close attenuation value as defined in Table 8 based on the band under test. DUT is set to 2.4 GHz operating frequency band with default configuration in the beginning of the test.
4. A Traffic Generator/Analyzer, sending the Ethernet packet to each peer STA, connects to the LAN interface (e.g., GE port) of the DUT.

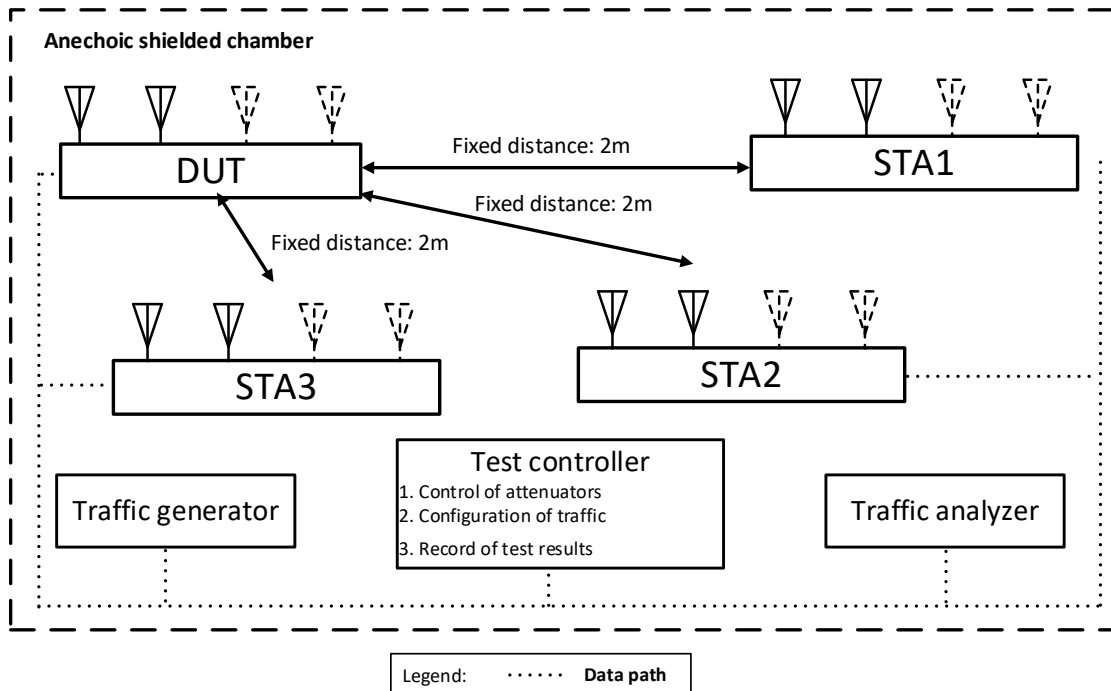


Figure 9: Test setup of Airtime Fairness Test

6.2.3.3 DUT Configuration

The test SHALL run under the default configuration.

6.2.3.4 Procedures

1. Establish the setup using default configuration for the 802.11n 2.4 GHz frequency band with NSS = 2 operating mode for STA1 and STA2. Use or configure a STA3 to only use 802.11b/g.
2. Associate STA1 and STA2 with DUT. Establish the LAN connection and wait for 10 seconds.
3. Measure the achievable downlink TCP throughput through STA1, using a test time of 120 seconds. Record this value as STA1_Throughput_Max_DL_1.
4. Measure the achievable downlink TCP throughput through STA2, using a test time of 120 seconds. Record this value as STA2_Throughput_Max_DL_1.
5. Configure the downlink UDP traffic streams to use a downlink data rate set to 75% of STA1_Throughput_Max_DL_1 for STA1 and 50% of STA2_Throughput_Max_DL_1 for STA2.
6. Simultaneously run the two UDP traffic streams for 120 seconds, recording the throughput for each stream. Record these values as STA1_Throughput_1 and STA2_Throughput_1 respectively.
7. Move STA2 to a medium distance to the DUT as defined in table Table 8 plus AAV defined in section 5.2.5. Wait for 10 seconds.
8. Measure the achievable downlink TCP throughput through STA2, using a test time of 120 seconds. Record this value as STA2_Throughput_Max_DL_2.
9. Configure the downlink UDP traffic streams to use a downlink data rate set to 75% of STA1_Throughput_Max_DL_1 for STA1 and 50% of STA2_Throughput_Max_DL_2 for STA2.
10. Simultaneously run the two UDP traffic streams for 120 seconds, recording the throughput for each stream. Record these values as STA1_Throughput_2 and STA2_Throughput_2 respectively.
11. Disassociate STA2 from the DUT. Revert to default test configuration, then replace STA 2 with STA 3, configured for the specified Wi-Fi operating mode. Establish the Wi-Fi connection between STA3 and DUT and wait for 10 seconds.
12. Measure the achievable downlink TCP throughput through STA3, using a test time of 120 seconds. Record this value as STA3_Throughput_Max_DL_3.
13. Configure the downlink UDP traffic streams to use a downlink data rate set to 75% of STA1_Throughput_Max_DL_1 for STA1 and 50% of STA3_Throughput_Max_DL_3 for STA3.
14. Simultaneously run the two UDP traffic streams for 120 seconds, recording the throughput for each stream. Record these values as STA1_Throughput_3 and STA3_Throughput_3 respectively.
15. Set the DUT to operating mode to 802.11ac 5 GHz frequency band with NSS = 2. Replace or reconfigure STA3 with a STA that uses only 802.11a. Repeat steps 2 through 14.
16. Set the DUT to operating mode to 802.11ax 2.4 GHz frequency band with NSS = 2. Replace or reconfigure STA3 with a STA that uses only 802.11n. Repeat steps 2 through 14.
17. Set the DUT to operating mode 802.11ax 5 GHz frequency band with NSS = 2. Replace or reconfigure STA3 with a STA that uses only 802.11ac. Repeat steps 2 through 14.

6.2.3.5 Metrics (Pass/Fail Criteria)

In order to pass the test case, the recorded results SHALL meet the Pass/Fail Criteria, described as following:

- a) For each UDP measurement, the throughput shall be at least 45% of the TCP Throughput Max speeds reported on the station being tested. This ensures that the AP properly limits the over-driven STA1 connection and gives the other station a fair amount of airtime.
- b) To verify over-all throughput while ensuring airtime fairness, the throughput of the DUT SHALL meet the requirements below.

For the test in 802.11n 2.4 GHz frequency bandNSS:

- 1) The summation of STA1_throughput_1 and STA2_throughput_1 SHALL be larger than 100 Mbps.
- 2) The summation of STA1_throughput_2 and STA2_throughput_2 SHALL be larger than 100 Mbps.
- 3) The summation of STA1_throughput_3 and STA3_throughput_3 SHALL be larger than 60 Mbps.

For the test in 802.11ac 5 GHz frequency band:

- 1) The summation of STA1_throughput_1 and STA2_throughput_1 SHALL be larger than 650 Mbps.
- 2) The summation of STA1_throughput_2 and STA2_throughput_2 SHALL be larger than 550 Mbps.

- 3) The summation of STA1_throughput_3 and STA3_throughput_3 SHALL be larger than 335 Mbps.
For the test in 802.11ax 2.4 GHz frequency band:
 - 1) The summation of STA1_throughput_1 and STA2_throughput_1 SHALL be larger than 190 Mbps.
 - 2) The summation of STA1_throughput_2 and STA2_throughput_2 SHALL be larger than 130 Mbps.
 - 3) The summation of STA1_throughput_3 and STA3_throughput_3 SHALL be larger than 95 Mbps.
- For the test in 802.11ax 5 GHz frequency band:
 - 1) The summation of STA1_throughput_1 and STA2_throughput_1 SHALL be larger than 900 Mbps.
 - 2) The summation of STA1_throughput_2 and STA2_throughput_2 SHALL be larger than 750 Mbps.
 - 3) The summation of STA1_throughput_3 and STA3_throughput_3 SHALL be larger than 600 Mbps.

6.2.4 Dual-band Throughput Test

6.2.4.1 Introduction

The Dual-band Throughput Test is intended to measure the throughput the DUT can support when concurrently connected to multiple stations on both the 2.4 and 5 GHz bands, or the 5 and 6 GHz bands, each operating with two spatial streams (see note 1). The purpose of this test cases is to detect cross band interference of the DUT's transmitter on the receiver. The weak link is needed to ensure DUT and STA are transmitting at the highest power and causing the most potential interference when the receiver is more susceptible to noise (low SNR). Note, each station is connected using either the 2.4 or 5 GHz band or the 5 or 6 GHz band, but not both bands simultaneously. This test requires at least 2 stations, located at the AAV as calibrated in 5.2.5 based on the band under test. The DUT will need to support at least 4 independent radio chains for this test case, two operating in the 2.4 GHz band and two operating in the 5 GHz band or two operating in the 5 GHz band and two operating in the 6 GHz band.

Note 1: If the DUT supports 2.4, 5 and 6 GHz band, the 5 GHz and 6 GHz bands will be tested for 802.11ax.

This test SHALL be MANDATORY for the test plan.

6.2.4.2 Setup

1. The test setup (shown in Figure 10) SHALL be located in the anechoic shielded chamber (see section 5.2.1 and 5.2.2), using 2 stations.
2. The peer STAs and DUT are placed at the AAV as calibrated in 5.2.5 based on the band under test.
3. Configure one station to enable only the 2.4 GHz band, configure the other station to enable only the 5 GHz band or configure one station to enable only the 5 GHz band, configure the other station to enable only the 6GHz band.
4. A Traffic Generator/Analyzer, sending the Ethernet packets, connects to the LAN interface (e.g., GE port) of the DUT.
5. TCP connections SHALL be used for Ethernet packet transmission in the test.
6. STA shall be configured to use 2 spatial steams.

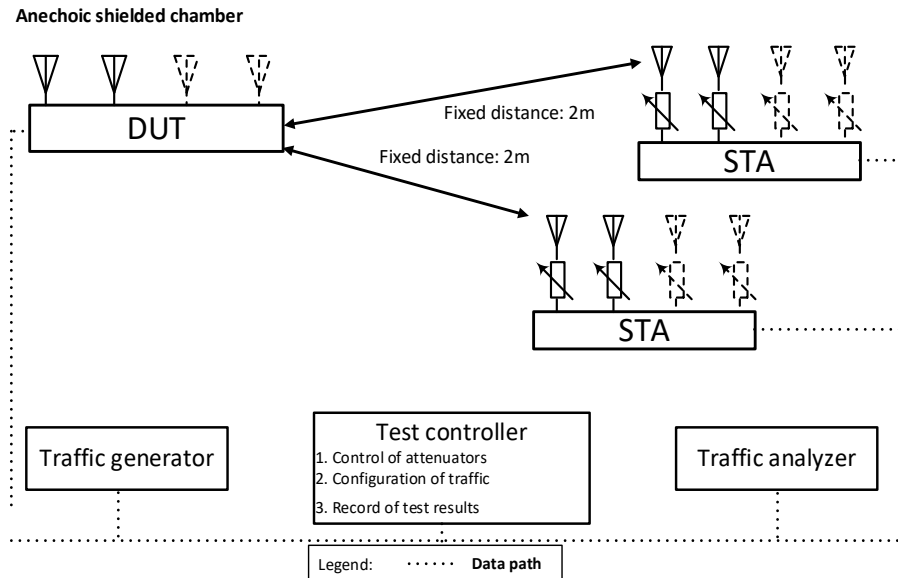


Figure 10: Test setup Dual-band Throughput Test

6.2.4.3 DUT configuration

The test SHALL run under the following configuration:

1. For DUT supporting only 2.4 and 5 GHz bands in the following different modes:
 - a. 802.11n and 802.11ac
 - b. 802.11ax 2.4 GHz and 802.11ax 5 GHz
2. For DUT supporting 2.4, 5 and 6 GHz bands in the following different modes:
 - a. 802.11n and 802.11ac
 - b. 802.11ax 5 GHz and 802.11ax 6 GHz

6.2.4.4 Procedures

1. Configure the working mode of DUT to enable both 802.11n and 802.11ac with the default configuration (see section 5.3).
2. Establish the LAN connection and allow all STA to associate with the DUT.
3. Simultaneously measure the downlink TCP throughput to all STA, using a test time of 120 seconds. TCP traffic rate shall be sent at the pass/fail rate in Table 24 for the test point.
4. Simultaneously measure the uplink TCP throughput to all STA, using a test time of 120 seconds. TCP traffic rate shall be sent at the pass/fail rate in Table 24 for the test point. Simultaneously measure the downlink TCP throughput to the 802.11n STA and the uplink TCP throughput to the 802.11ac STA. TCP traffic rate shall be over the pass/fail rate in Table 24 for the test point.
5. Simultaneously measure the uplink TCP throughput to the 802.11n STA and the downlink TCP throughput to the 802.11ac STA. TCP traffic rate shall be sent at the pass/fail rate in Table 24 for the test point.
6. Repeat steps 1 through 6 with the attenuators set to the medium distance as defined in Table 8 for the respective band.
7. Repeat steps 1 through 6 with the attenuators set to the far distance as defined in Table 8 for the respective band.
8. Repeat steps 1 through 8 for each configuration listed above in 6.2.4.3 that applies to the DUT.

Note: The test result can be slightly affected by the capability of Peer STA. The test can be conducted with different peer STAs with chipsets from different vendors. The calculated average throughput then can be averaged again in the dimension of chipset.

Note: The simultaneous measurements imply 2 TCP measurement streams connecting two IP hosts, each located at one STA.

6.2.4.5 Metrics (Pass/Fail Criteria)

In order to pass the test case, the recorded results SHALL meet the Pass/Fail Criteria, described as following:

1. For each attenuation value, at least 7 of the 8 measured average throughputs SHALL meet the 95% of the performance requirements of Table 24.

Table 24: Dual-band Throughput Test Requirements

Test Point	Additional Attenuation (dB)	Description	Throughput Requirements					
			2.4 GHz		5 GHz		6 GHz	
			Downlink (Mbps)	Uplink (Mbps)	Downlink (Mbps)	Uplink (Mbps)	Downlink (Mbps)	Uplink (Mbps)
1	close	Simultaneous downlink on 802.11n and 802.11ac	85	N/A	550	N/A	N/A	N/A
2	close	Simultaneous uplink on 802.11n and 802.11ac	N/A	85	N/A	550	N/A	N/A
3	close	Downlink through 802.11n, uplink through 802.11ac	85	N/A	N/A	550	N/A	N/A
4	close	Uplink through 802.11n, downlink through 802.11ac	N/A	85	550	N/A	N/A	N/A
5	medium	Simultaneous downlink on 802.11n and 802.11ac	60	N/A	390	N/A	N/A	N/A
6	medium	Simultaneous uplink on 802.11n and 802.11ac	N/A	60	N/A	390	N/A	N/A
7	medium	Downlink through 802.11n, uplink through 802.11ac	60	N/A	N/A	390	N/A	N/A
8	medium	Uplink through 802.11n, downlink through 802.11ac	N/A	60	390	N/A	N/A	N/A
9	far	Simultaneous downlink on 802.11n and 802.11ac	15	N/A	115	N/A	N/A	N/A
10	far	Simultaneous uplink on 802.11n and 802.11ac	N/A	15	N/A	115	N/A	N/A

11	far	Downlink through 802.11n, uplink through 802.11ac	15	N/A	N/A	115	N/A	N/A
12	far	Uplink through 802.11n, downlink through 802.11ac	N/A	15	115	N/A	N/A	N/A
13	close	Simultaneous downlink on 802.11ax 2.4 GHz and 802.11ax 5 GHz	115	N/A	725	N/A	N/A	N/A
14	close	Simultaneous uplink on 802.11ax 2.4 GHz and 802.11ax 5 GHz	N/A	115	N/A	725	N/A	N/A
15	close	Downlink through 802.11ax 2.4 GHz, uplink through 802.11ax 5 GHz	115	N/A	N/A	725	N/A	N/A
16	close	Uplink through 802.11ax 2.4 GHz, downlink through 802.11ax 5 GHz	N/A	115	725	N/A	N/A	N/A
17	medium	Simultaneous downlink on 802.11ax 2.4 GHz and 802.11ax 5 GHz	75	N/A	470	N/A	N/A	N/A
18	medium	Simultaneous uplink on 802.11ax 2.4 GHz and 802.11ax 5 GHz	N/A	75	N/A	470	N/A	N/A
19	medium	Downlink through 802.11ax 2.4 GHz, uplink through 802.11ax 5 GHz	75	N/A	N/A	470	N/A	N/A
20	medium	Uplink through 802.11ax 2.4 GHz, downlink through 802.11ax 5 GHz	N/A	75	470	N/A	N/A	N/A
21	far	Simultaneous downlink on 802.11ax 2.4 GHz and 802.11ax 5 GHz	20	N/A	125	N/A	N/A	N/A
22	far	Simultaneous uplink on 802.11ax 2.4 GHz and 802.11ax 5 GHz	N/A	20	N/A	125	N/A	N/A
23	far	Downlink through 802.11ax 2.4 GHz, uplink through 802.11ax 5 GHz	20	N/A	N/A	125	N/A	N/A
24	far	Uplink through 802.11ax 2.4 GHz, downlink through 802.11ax 5 GHz	N/A	20	125	N/A	N/A	N/A
25	close	Simultaneous downlink on 802.11ax 5 GHz and 802.11ax 6 GHz	N/A	N/A	725	N/A	1275	N/A

26	close	Simultaneous uplink on 802.11ax 5 GHz and 802.11ax 6 GHz	N/A	N/A	N/A	725	N/A	1275
27	close	Downlink through 802.11ax 5 GHz, uplink through 802.11ax 6 GHz	N/A	N/A	725	N/A	N/A	1275
28	close	Uplink through 802.11ax 5 GHz, downlink through 802.11ax 6 GHz	N/A	N/A	N/A	725	1275	N/A
29	medium	Simultaneous downlink on 802.11ax 5 GHz and 802.11ax 6 GHz	N/A	N/A	470	N/A	850	N/A
30	medium	Simultaneous uplink on 802.11ax 5 GHz and 802.11ax 6 GHz	N/A	N/A	N/A	470	N/A	850
31	medium	Downlink through 802.11ax 5 GHz, uplink through 802.11ax 6 GHz	N/A	N/A	470	N/A	N/A	850
32	medium	Uplink through 802.11ax 5 GHz, downlink through 802.11ax 6 GHz	N/A	N/A	N/A	470	850	N/A
33	far	Simultaneous downlink on 802.11ax 5 GHz and 802.11ax 6 GHz	N/A	N/A	125	N/A	510	N/A
34	far	Simultaneous uplink on 802.11ax 5 GHz and 802.11ax 6 GHz	N/A	N/A	N/A	125	N/A	510
35	far	Downlink through 802.11ax 5 GHz, uplink through 802.11ax 6 GHz	N/A	N/A	125	N/A	N/A	510
36	far	Uplink through 802.11ax 5 GHz, downlink through 802.11ax 6 GHz	N/A	N/A	N/A	125	510	N/A
Notes:								
1. The requirements per each row apply to measurements made simultaneously (at the same time) for the described test point.								
Editor's Note: Need to take into account the link speed of the LAN port for the pass fail in the 5 GHz / 6 GHz case above for the lower attenuation values for the double DS and US cases.								

6.2.5 Bidirectional Throughput Test

6.2.5.1 Introduction

The Bidirectional Throughput Test measures the uplink and downlink simultaneously achieved through the DUT and a station.

This test SHALL be MANDATORY for the test plan.

6.2.5.2 Setup

1. The test setup (shown in Figure 8) SHALL be located in the anechoic shielded chamber (see section 5.2.1 and 5.2.2).
2. The peer STA and DUT are placed at the AAV as calibrated in 5.2.5 based on the band under test.
3. Configure the DUT and STA to use the 2.4 GHz band, per the settings in Section 5.3.
4. A Traffic Generator/Analyzer, sending the Ethernet packets, connects to the LAN interface (e.g., GE port) of the DUT. TCP connections SHALL be used for Ethernet packet transmission in the test.
5. STA shall be configured to use 2 spatial streams.

6.2.5.3 DUT configuration

The test SHALL run under the following configuration:

- 1) The STA shall be configured in different modes:
 - a) 802.11n
 - b) 802.11ac
 - c) 802.11ax over 2.4 GHz
 - d) 802.11ax over 5 GHz
 - e) 802.11ax over 6 GHz

6.2.5.4 Procedures

1. Establish the LAN connection and allow the STA to associate with the DUT.
2. Configure the attenuator to the close value as defined in Table 8 for the respective band.
3. Measure the achievable downlink TCP throughput, using a test time of 120 seconds. Record this value as Throughput_Max_DL.
4. Measure the achievable uplink TCP throughput, using a test time of 120 seconds. Record this value as Throughput_Max_UL.
5. Configure bidirectional UDP traffic streams to use a downlink data rate set to 45% of Throughput_Max_DL and an uplink data rate of 45% of Throughput_Max_UL. Record these values as Throughput_DL and Throughput_UL respectively.
6. Simultaneously run the bidirectional UDP traffic for 120 seconds, recording the number of packets transmitted, received, and dropped in each direction.
7. Calculate the PACKET_LOSS_RATIO_DL and PACKET_LOSS_RATIO_UL as the number of lost packets divided by the total number of packets transmitted.
8. Repeat steps 1 through 7 for with the attenuator settings medium and far as defined in Table 8 for the respective band.
9. Repeat steps 1 through 8 for each configuration listed above in Section 6.2.5.3.

Note: The test result MAY be slightly affected by the capability of Peer STA. The test can be conducted with different peer STAs with chipsets from different vendors. The calculated average throughput then can be averaged again in the dimension of chipset.

6.2.5.5 Metrics (Pass/Fail Criteria)

In order to pass the test case, the recorded results SHALL meet the Pass/Fail Criteria, described as following:

1. Each measured PACKET_LOSS_RATIO_DL and PACKET_LOSS_RATIO_UL SHALL be less than or equal to 1E-4.

6.2.6 Latency Test

6.2.6.1 Introduction

Excessive latency leads to poor user experience and excessive TCP retransmits and inefficiencies in how TCP learns the optimal throughput. Wi-Fi segregates traffic destined to each peer, which makes keeping latency low and also offering good throughput with many active peers difficult. The Latency test intends to verify that latency and throughput performs well under low, high, and maximum AP traffic load, with 1 and 32 stations.

This test SHALL be MANDATORY for the test plan.

6.2.6.2 Setup

1. The test setup (shown in Figure 8) SHALL be located in the anechoic shielded chamber (see section 5.2.1 and 5.2.2).
2. The peer STAs and DUT are placed at the AAV as calibrated in section 5.2.5 based on the profile under test.
3. Configure the DUT and 32 STA to use the 2.4 GHz band, per the settings in Section 5.3.
4. A Traffic Generator/Analyzer, sending the Ethernet packets, connects to the LAN interface of the DUT.
5. STA shall be configured to use 2 spatial streams.

6.2.6.3 DUT configuration

The test SHALL run under the following configuration:

- 1) Stations shall be configured for different modes:
 - a) 802.11n
 - b) 802.11ac
 - c) 802.11ax over 2.4 GHz
 - d) 802.11ax over 5 GHz
 - e) 802.11ax over 6 GHz

6.2.6.4 Procedures

1. Configure the working mode of STAs to 802.11n with default configuration.

2. Establish the LAN connection and allow one of 32 stations to associate with the DUT.
3. Create AP to Station (download) TCP stream, and run for 120 seconds, record throughput as 'maximum_load'. Stop this connection.
4. Calculate offered_load as 1% of maximum_load
5. Create 4 TCP streams on each active station, each configured for Upload and Download rate of offered_load / (8 * active_station_count).
6. Create 1 UDP stream on each active station, configured for 56kbps traffic Upload and 56kbps traffic Download.
7. Start all TCP and UDP connections. Wait 30 seconds to let traffic settle.
8. Every 10 seconds for 120 seconds, record one-way download latency over the last 10 seconds for each UDP connection. Depending on test equipment features, this may mean you need to start/stop the UDP every 10 seconds or clear the UDP connection counters.
9. Calculate offered_load as 70% of maximum_load, and repeat steps 5 - 8 inclusive.
10. Calculate offered_load as 125% of maximum_load, and repeat steps 5 - 8 inclusive.
11. Allow the other 31 stations to associate, and repeat steps 4 - 10 inclusive with all 32 stations active.
12. Repeat steps 2 through 11 for each configuration listed above in Section 6.2.6.3

6.2.6.5 Metrics (Pass/Fail Criteria)

- 1) For each test configuration running at 1% of maximum load: Average of all UDP latency samples must be less than 15ms.
- 2) For each test configuration running at 1% of maximum load: Maximum of all UDP latency samples must be less than 25ms.
- 3) For each test configuration running at 70% of maximum load: Average of all UDP latency samples must be less than 25ms.
- 4) For each test configuration running at 70% of maximum load: Maximum of all UDP latency samples must be less than 45ms.
- 5) For each test configuration running at 125% of maximum load: Average of all UDP latency samples must be less than 55ms.
- 6) For each test configuration running at 125% of maximum load: Maximum of all UDP latency samples must be less than 105ms.
- 7) For each test configuration: Each UDP connection upload throughput must be at least 1/2 of requested UDP speed for final 10-second test interval.
- 8) For each test configuration: Each UDP connection download throughput must be at least 1/2 of requested UDP speed for final 10-second test interval.

6.2.7 QoS Test

6.2.7.1 Introduction

Quality of Service Test verifies the capability of Wi-Fi device to ensure higher priority traffic gets prioritized over lower priority traffic. Best Effort QoS TCP traffic is used to determine maximum capacity of the station. The combinations of VO, VI, BE, BK QoS UDP traffic is requested to run at 75% of the TCP throughput. This overdrives the AP and causes it to drop frames. The pass/fail criteria is that the higher QoS stream gets more priority than the lower QoS stream, while maintaining good over-all throughput. This test case is not exercising WMM contention.

This test SHALL be OPTIONAL for the test plan.

6.2.7.2 Setup

1. The test setup (shown in Figure 8) SHALL be located in the anechoic shielded chamber (see section 5.2.1 and 5.2.2).
2. The peer STA and DUT are placed at the AAV as calibrated in section 5.2.5 based on the profile under test.
3. Configure the DUT and STA to use the 2.4 GHz band, per the settings in Section 5.3.
4. A Traffic Generator/Analyzer, sending the Ethernet packets, connects to the LAN interface (e.g., GE port) of the DUT.
5. STA shall be configured to use 2 spatial steams, if the DUT only has 1 Gbps LAN port support the STA shall be configured to use 1 spatial stream.
6. How TCP / UDP traffic streams are mapped to QoS queues is out of scope and implementation specific and may require implementation specific configurations on the DUT.

6.2.7.3 DUT configuration

The test SHALL run under the following configuration:

- 1) The DUT shall be configured for different modes:
 - a) 802.11n
 - b) 802.11ac
 - c) 802.11ax over 2.4 GHz
 - d) 802.11ax over 5 GHz

Table 25: QoS Combinations

First Traffic Stream	Second Traffic Stream
Voice	Video
Voice	Best Effort
Voice	Background
Video	Best Effort
Video	Background
Best Effort	Background

6.2.7.4 Procedures

1. Establish the setup using default configuration for the 802.11n 2.4 GHz frequency band with NSS = 2 operating mode for STA.
2. Associate STA with DUT. Establish the LAN connection and wait for 10 seconds.
3. Measure the achievable downlink Best Effort QoS TCP throughput through STA, using a test time of 120 seconds. Record this value as STA_Throughput_Max_DL_1. Stop the TCP traffic.
4. Configure the first downlink UDP Traffic stream to use Voice QoS classification.
5. Configure the second downlink UDP Traffic stream to use Video QoS classification.
6. Configure the first downlink UDP traffic stream to use a downlink data rate set to 75% of STA_Throughput_Max_DL_1..
7. Configure the second downlink UDP traffic stream to use a downlink data rate set to 75% of STA_Throughput_Max_DL_1.
8. Simultaneously run the two UDP traffic streams for 120 seconds, recording the throughput for each stream as connection_1_throughput and connection_2_throughput.
9. Repeat steps 6 through 8 for each QoS combination in table 25.

10. .
11. Set the DUT to operating mode to 802.11ac 5 GHz frequency band with NSS = 1. Repeat steps 2 through 9.
12. Set the DUT to operating mode to 802.11ax 2.4 GHz frequency band with NSS = 2. Repeat steps 2 through 9.
13. Set the DUT to operating mode to 802.11ax 5 GHz frequency band with NSS = 1. Repeat steps 2 through 9.

6.2.7.5 Metrics (Pass/Fail)

For each combination of QoS, calculate the throughput ratio of connection_1_throughput / connection_2_throughput, each combination must meet the values defined in Table 26.

Table 26 : Pass/Fail Metrics for QoS Test

Traffic Pairs	Throughput Ratio	Percentage of Combined Throughput of STA throughput Max DL 1
Voice QoS / Video QoS	1.1	90%
Voice QoS / Best Effort	1.1	90%
Voice QoS / Background	1.2	90%
Video QoS / Best Effort	1.1	90%
Video QoS / Background	1.2	90%
Best Effort / Background	1.2	90%

6.2.8 Multi-band Throughput Test

6.2.8.1 Introduction

The Multi-band Throughput Test measures the throughput the DUT can support when concurrently connected to multiple stations on all the 2.4, 5 and 6 GHz bands, each operating with two spatial streams. The purpose of these additional test cases is to detect cross band interference of the DUT's transmitter on the receiver and to confirm the DUT has enough resources to serve multiple bands concurrently. The weak link is needed to ensure DUT and STA are transmitting at the highest power and causing the most potential interference when the receiver is more susceptible to noise (low SNR). This test requires 3 stations, located at the AVV as defined in section 5.2.5. The DUT will need to support at least 6 independent radio chains for this test case, two operating in the 2.4 GHz band, two in the 5 GHz band, and two operating in the 6 GHz band.

This test SHALL be MANDATORY for the test plan if DUT supports all 3 bands and supports a LAN port speed of 2.5Gbps or above.

6.2.8.2 Setup

1. The test setup (shown in Figure 11) SHALL be located in the anechoic shielded chamber (see section 5.2.1 and 5.2.2), using 3 stations.
2. The peer STAs and DUT are placed at the AAV as calibrated in section 5.2.5 based on the profile under test.
3. Additional attenuation is added in each RF chain of STA to simulate the incremental distance.

4. Configure one station to enable only the 2.4 GHz band, configure the other station to enable only the 5 GHz band, configure the other station to enable only the 6 GHz band.
5. A Traffic Generator/Analyzer, sending the Ethernet packets, connects to the LAN interface (e.g., GE port) of the DUT.
6. TCP connections SHALL be used for Ethernet packet transmission in the test.
7. STA shall be configured to use 2 spatial steams.

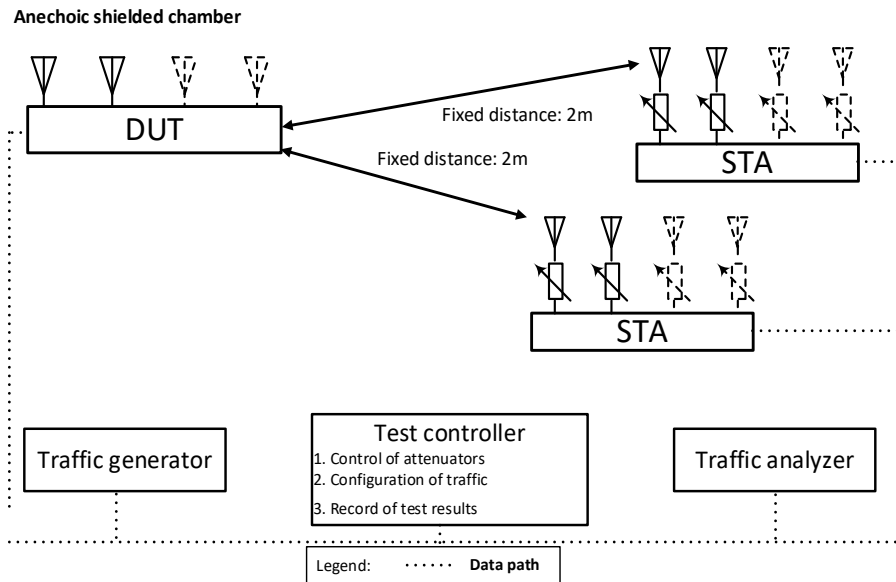


Figure 11: Test setup Multi-band Throughput Test

6.2.8.3 DUT configuration

The test SHALL run under the following configuration:

1. For DUT supporting 2.4, 5 and 6 GHz bands in the following different modes:
 - a. 802.11ax 2.4 GHz, 802.11ax 5 GHz and 802.11ax 6 GHz

6.2.8.4 Procedures

1. Configure the working mode of DUT to enable 802.11ax mode on all bands with the default configuration (see section 5.3).
2. Set attenuator to the close value as defined in Table 8 for the respective band.
3. Establish the LAN connection and allow all STA to associate with the DUT.
4. Simultaneously measure the downlink TCP throughput to all STA, using a test time of 120 seconds. TCP traffic rate shall be sent at the rate in Table 27 for the test point.
5. Simultaneously measure the uplink TCP throughput to all STA, using a test time of 120 seconds. TCP traffic rate shall be sent at the rate in Table 27 for the test point.
6. Simultaneously measure the downlink TCP throughput to the 2.4 and 5 GHz STA and uplink TCP throughput from the 6 GHz STA using a test time of 120 seconds. TCP traffic rate shall be sent at the rate in Table 27 for the test point.
7. Simultaneously measure the downlink TCP throughput to the 2.4 and 6 GHz STA and uplink TCP throughput from the 5 GHz STA using a test time of 120 seconds. TCP traffic rate shall be sent at the rate in Table 27 for the test point.
8. Repeat steps 3 through 7 with the attenuators set to the medium value as defined in Table 8 for the respective band.

- Repeat steps 3 through 7 with the attenuators set to the far value as defined in Table 8 for the respective band.

Note: The test result MAY be slightly affected by the capability of Peer STA. The test can be conducted with different peer STAs with chipsets from different vendors. The calculated average throughput then can be averaged again in the dimension of chipset.

Note: The simultaneous measurements imply 3 TCP measurement streams connecting three IP hosts, each located at one STA.

6.2.8.5 Metrics (Pass/Fail Criteria)

In order to pass the test case, the recorded results SHALL meet the Pass/Fail Criteria, described as following:

- For each attenuation value, at least 11 of the 12 measured average throughputs SHALL meet 95% of the performance requirements of Table 27.

Table 27: Multi-band Throughput Test Requirements

Test Point	Additional Attenuation (dB)	Description	Throughput Requirements					
			2.4 GHz		5 GHz		6 GHz	
			Downlink (Mbps)	Uplink (Mbps)	Downlink (Mbps)	Uplink (Mbps)	Downlink (Mbps)	Uplink (Mbps)
1	close	Simultaneous downlink	150	N/A	675	N/A	1000	N/A
2	close	Simultaneous uplink	N/A	150	N/A	675	N/A	1000
3	close	Downlink through 2.4 and 5 GHz, uplink through 6 GHz	150	N/A	675	N/A	N/A	1000
4	close	Downlink through 2.4 and 6 GHz, uplink through 5 GHz	N/A	150	N/A	675	TBD	1000
5	medium	Simultaneous downlink	130	N/A	380	N/A	500	N/A
6	medium	Simultaneous uplink	N/A	130	N/A	380	N/A	500
7	medium	Downlink through 2.4 and 5 GHz, uplink through 6 GHz	130	N/A	380	N/A	N/A	500
8	medium	Downlink through 2.4 and 6 GHz, uplink through 5 GHz	N/A	130	N/A	380	500	N/A
9	far	Simultaneous downlink	75	N/A	100	N/A	75	N/A
10	far	Simultaneous uplink	N/A	75	N/A	100	N/A	75
11	far	Downlink through 2.4 and 5 GHz, uplink through 6 GHz	75	N/A	100	N/A	N/A	75
12	far	Downlink through 2.4 and 6 GHz, uplink through 5 GHz	N/A	75	N/A	100	75	N/A
Notes:								

<ol style="list-style-type: none"> 1. 2. <p>Editor's Note: Need to take into account the link speed of the LAN port for the pass fail in the 5GHz / 6GHz case above for the lower attenuation values for the double DS and US cases.</p>	<p>The requirements per each row apply to measurements made simultaneously (at the same time) for the described test point.</p> <p>For 802.11ax, all performance requirements refer to guard interval of GI =800 ns.</p>		
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6.3 Coverage

6.3.1 Range Versus Rate Test

6.3.1.1 Introduction

Range versus rate test measures the baseband and RF chain performance of Wi-Fi device. The attenuation of signals due to increasing range is achieved by using attenuator(s) in the RF path between the AP and STA.

This test SHALL be MANDATORY for the test plan.

6.3.1.2 Setup

1. The test setup (shown in Figure 12) SHALL be located in the anechoic shielded chamber (see section 5.2.1 and 5.2.2).
2. A Traffic Generator/Analyzer, sending the Ethernet packets, connects to the LAN interface (e.g., GE port) of the DUT.
3. The peer STA and DUT are placed at the AAV as calibrated in section 5.2.5 based on the profile under test.
4. Additional attenuation is added to simulate the incremental distance. The specific attenuation values used for testing are defined in 6.3.1.3.
5. The host SHALL send the Ethernet packet at the maximum rate which the DUT can achieve theoretically.
6. TCP connection SHALL be used for Ethernet packet transmission in the test.

Note 1: The attenuators need to be capable of providing attenuation steps between 0dB ~ 56dB for the selected operating frequency band.

Note 2: A channel simulator, which emulates a specific real environment, MAY be used to replace the simple attenuators for more comprehensive test.

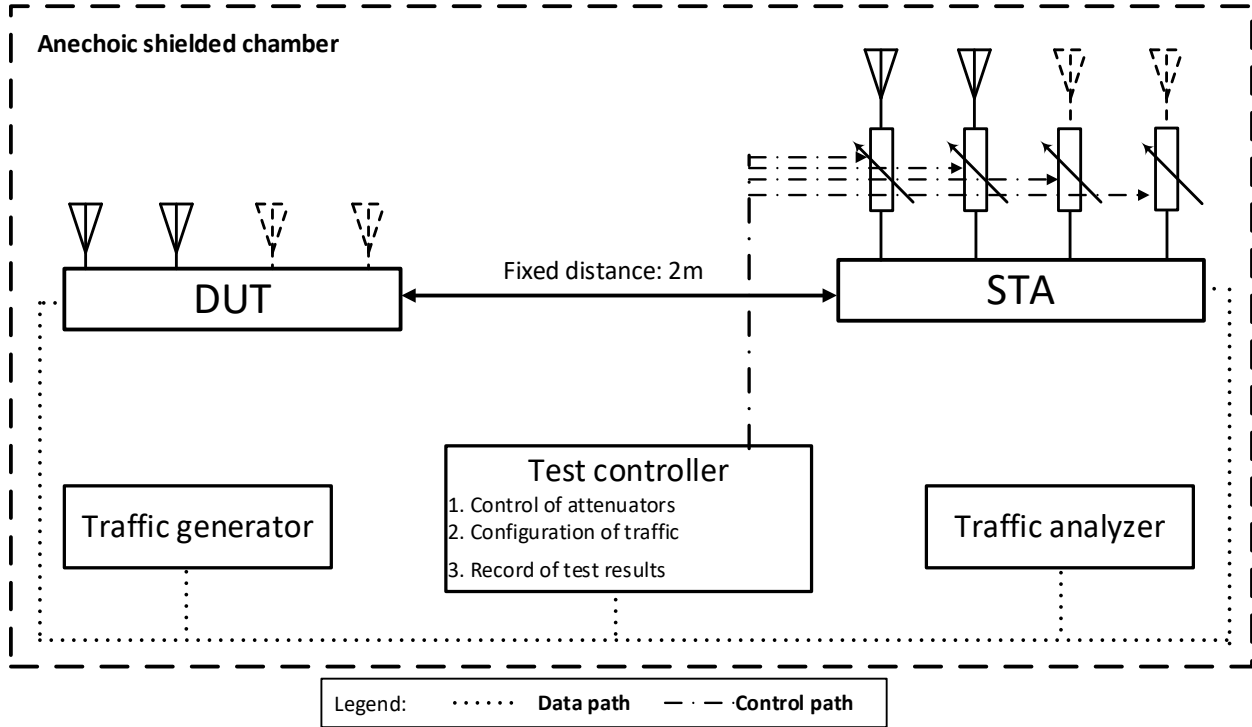


Figure 12: Test setup of Range Versus Rate Test

6.3.1.3 DUT Configuration

The test SHALL run under the following configuration:

1. General configuration for DUT/STA working mode, bandwidth and number of RF chains:

Table 28: General configuration for range vs rate test

Wi-Fi configuration (DUT and Peer STA)	Bandwidth (MHz)
802.11n (NSS=2)	20
802.11ac (NSS=2)	80
802.11ax (2.4 GHz, NSS=2)	20
802.11ax (5 GHz, NSS=2)	80
802.11ax (6 GHz, NSS=2)	160

2. Additional attenuation for STA RF chain during the test, see Table 29.

Table 29: Additional attenuation for STA RF chain during the test

Additional attenuation for test of 802.11n and 802.11ax 2.4 GHz	0 dB (default), 6 dB, 12 dB, 18 dB, 24 dB, 30 dB, 36 dB, 39 dB, 41 dB, 43 dB, 45 dB, 47 dB, 49 dB
Additional attenuation for test of 802.11ac and 802.11ax 5 GHz	0 dB (default), 6 dB, 12 dB, 18 dB, 24 dB, 30 dB, 36 dB, 39 dB, 41 dB, 43 dB, 45 dB, 47 dB, 49 dB

Additional attenuation for test of 802.11ax 6 GHz	0 dB (default), 3 dB, 6 dB, 9 dB, 12 dB, 15 dB, 18 dB, 21 dB, 24 dB, 27 dB, 30 dB
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6.3.1.4 Procedures

1. Configure the attenuator with 0 dB attenuation. Configure the working mode of DUT to 802.11n and operating frequency band to 2.4 GHz with default configuration as in Table 28.
2. Establish the LAN connection and allow STA to associate with the DUT.
3. Measure the downlink TCP throughput to the STA, using a test time of 120 seconds.
4. Measure the uplink TCP throughput to the DUT, using a test time of 120 seconds.
5. Repeat step 2-4 for all attenuation values for the respective band as define in Table 29 .
6. Configure the attenuator with 0 dB attenuation. Repeat steps 2-5 for all configurations defined in Table 28.

Note: The test result MAY be slightly affected by the capability of Peer STA. The test MAY be conducted with different peer STAs with chipsets from different vendors. The calculated average throughput then is averaged again in the dimension of chipset.

6.3.1.5 Metrics (Pass/Fail Criteria)

In order to pass the test case, the recorded results SHALL meet the Pass/Fail Criteria, described as following:

The measured average throughput SHALL meet the performance requirement of Table 30. For each operating mode (i.e., 802.11n or 802.11ax over 5 GHz), no more than 2 test points SHALL fall below the throughput requirement.

Table 30: The throughput requirement

Attenuation (dB)	802.11n NSS = 2		802.11ac NSS = 2		802.11ax 2.4 GHz NSS = 2		802.11ax 5 GHz NSS = 2		Attenuation (dB)	802.11ax 6 GHz NSS = 2	
	Throughput Requirement (Mbps)		Throughput Requirement (Mbps)		Throughput Requirement (Mbps)		Throughput Requirement (Mbps)			Throughput Requirement (Mbps)	
	DL	UL	DL	UL	DL	UL	DL	UL		DL	UL
0	100	100	650	650	180	180	880	880	0	1500	1500
6	100	100	650	650	180	180	855	855	3	1400	1400
12	100	100	645	645	180	180	820	820	6	1300	1300
18	100	100	525	525	145	145	700	700	8	1200	1200
24	90	90	460	460	135	135	555	555	12	1100	1100
30	70	70	335	335	90	90	395	395	15	1000	1000
36	45	45	180	180	55	55	215	215	18	900	900
39	40	40	135	135	35	35	150	150	21	800	800
41	25	25	115	115	30	30	135	135	24	700	700
43	20	20	85	85	25	25	85	85	27	600	600

45	15	15	60	60	15	15	75	75	30	400	400
47	8	8	40	40	15	15	45	45	-		
49	5	5	20	20	10	10	40	40	-		

6.3.2 Spatial consistency test

6.3.2.1 Introduction

Spatial consistency verifies the Wi-Fi signal consistency in spatial domain.

This test SHALL be MANDATORY for the test plan.

6.3.2.2 Setup

1. The test setup (shown in Figure 13) SHALL be located in the anechoic shielded chamber (see section 5.2.1 and 5.2.2).
2. The STA and DUT are placed at the AAV as calibrated in section 5.2.5 based on the profile under test. DUT is fixed in a two-dimensional rotation platform.
3. A Traffic Generator/Analyzer, sending the Ethernet packet, connects to the LAN interface (e.g., GE port) of the DUT. The Peer STA receives the Wi-Fi packet from the DUT through air interface.
4. Additional attenuation is added to simulate the incremental distance. The concrete values are defined in 6.3.2.3.
5. TCP connection SHALL be used for Ethernet packet transmission in the test.

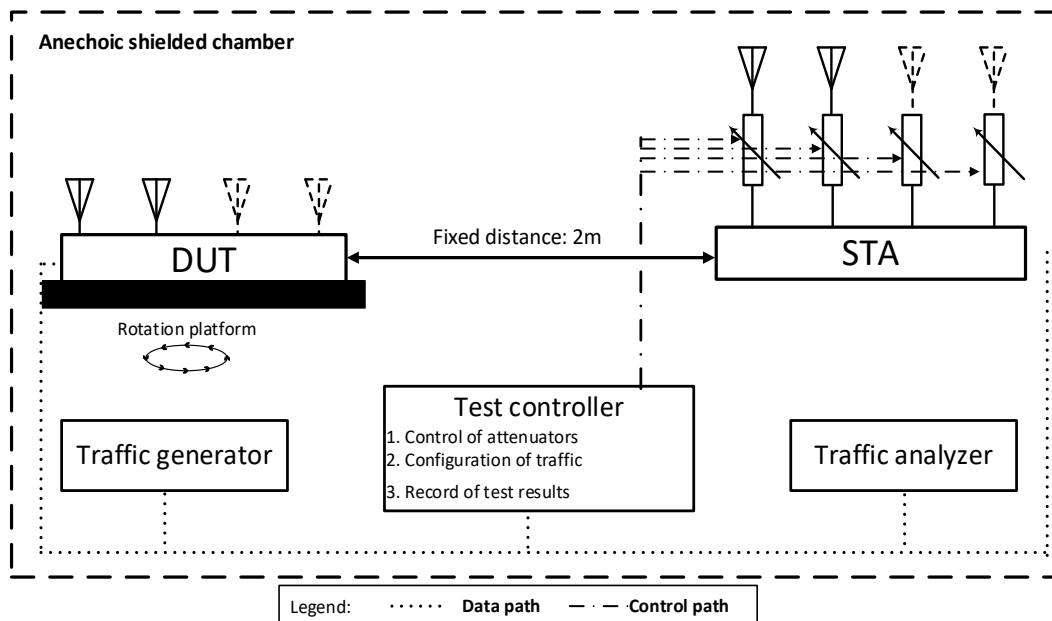


Figure 13: Test setup of Spatial Consistency Test

6.3.2.3 DUT Configuration

The test SHALL run under the following configuration if applicable:

1. General configuration for DUT/STA working mode, bandwidth and number of RF chains:

Table 31: General configuration for spatial consistency test

Wi-Fi configuration (Bandwidth (MHz)
802.11n (NSS=2)	20
802.11ac (NSS=2)	80
802.11ax (2.4 GHz, NSS=2)	20
802.11ax (5 GHz, NSS=2)	80
802.11ax (6 GHz, NSS=2)	160

2. See Table 8 for attenuation setting for STA RF chain during the test.

6.3.2.4 Procedures

1. Configure the working mode of DUT to 802.11n, operating frequency band to 2.4 GHz with default configuration.
2. Establish the LAN connection and allow STA to associate with to the DUT.
3. Measure the downlink TCP throughput to the STA, using a test time of 60 seconds. Wait for 10 seconds. Measure the uplink TCP throughput to the STA, using a test time of 60 seconds.
4. Rotate the DUT platform by 30° and repeat Step 3 until the platform has been rotated by 360°.
5. Reset the position of the DUT to 0°.
6. Repeat steps 2-5 for each attenuation value as defined in Table 8 until all the attenuation values have been tested.
7. Repeat steps 2-6 for all supported configurations as defined in Table 31.

Note: The test result MAY be slightly affected by the capability of Peer STA. The test MAY be conducted with multiple peer STAs with chipsets from different vendors. The calculated average throughput then is averaged again in the dimension of chipset.

6.3.2.5 Metrics (Pass/Fail Criteria)

In order to pass the test case, the recorded results SHALL meet the Pass/Fail Criteria, described as following:

- a) The average throughput measured at each angle SHALL meet the requirements in Table 32 for at least 10 of the 12 measurement points (rotation angle) for each operating mode and attenuator setting.

Table 32: Pass/Fail criteria for spatial consistency test by performance

Wi-Fi configuration	Bandwidth (MHz)	Throughput under different attenuation (Mbps)					
		Close signals		Medium signals		Far signals	
		DL	UL	DL	UL	DL	UL

802.11n (NSS=2)	20	85	85	60	60	15	15
802.11ac (NSS=2)	80	550	550	390	390	115	115
802.11ax (2.4 GHz, NSS=2)	20	155	155	75	75	20	20
802.11ax (5 GHz, NSS=2)	80	725	725	470	470	125	125
802.11ax (6 GHz, NSS=2)	160	1275	1275	850	850	510	510

- b) If any throughput measurement fails to meet the requirements of Table 32, the following requirement SHALL also apply, the maximum variation during rotation SHALL satisfy the requirements in Table 33:

Note: The variation at each specific attenuation is calculated as the difference between the minimum throughput value and the average throughput value, divided by the average throughput value over all rotations.

Table 33: Pass/Fail criteria for spatial consistency test by variation

Wi-Fi configuration	Bandwidth (MHz)	Variation under different attenuation (%)					
		Close signals		Medium signals		Far signals	
		DL	UL	DL	UL	DL	UL
11n (NSS=2)	20	30%	30%	30%	30%	30%	30%
11ac (NSS=2)	80	40%	40%	40%	40%	40%	40%
802.11ax (2.4 GHz, NSS=2)	20	30%	30%	30%	30%	30%	30%
802.11ax (5 GHz, NSS=2)	80	40%	40%	40%	40%	40%	40%
802.11ax (6 GHz, NSS=2)	160	40%	40%	40%	40%	40%	40%

6.3.3 802.11ax Peak Performance Test

6.3.3.1 Introduction

This test case examines the maximum performance expected from a DUT supporting 802.11ax with the following additional capabilities beyond the default configuration: 4 spatial streams, 160 MHz Channels.

This test SHALL be conditionally MANDATORY for the test plan, where each Wi-Fi configuration listed in Table 34 supported by the DUT SHALL be tested.

6.3.3.2 Setup

1. The test setup (shown in Figure 6) SHALL be located in the anechoic shielded chamber (see section 5.2.1 and 5.2.2).
2. The peer STA and DUT are placed at the AAV as calibrated in section 5.2.5 based on the profile under test.
3. A Traffic Generator/Analyzer, sending the Ethernet packets, connects to the LAN interface (e.g., GE port) of the DUT.
4. TCP connection(s) SHALL be used to measure the throughput between the STA and DUT.

6.3.3.3 DUT Configuration

The STA and DUT SHALL be configured for the following operating modes during this testing.

Table 34: Wi-Fi configuration for 802.11ax Peak Performance Test

Wi-Fi Config	Configuration Description
Config 1	802.11ax, 2.4 GHz, NSS = 2, BW = 40 MHz
Config 2	802.11ax, 5 GHz, NSS = 2, BW = 160 MHz
Config 3	802.11ax, 5 GHz, NSS = 4, BW = 160 MHz
Config 4	802.11ax, 5 GHz, NSS = 8, BW = 160 MHz

6.3.3.4 Procedures

1. Configure the operating mode of the DUT and STA to the first configuration in Table 34.
2. Establish the LAN connection and allow STA to associate with the DUT.
3. Measure the downlink TCP throughput to the STA, using a test time of 120 seconds.
4. Measure the uplink TCP throughput to the STA, using a test time of 120 seconds.
5. Repeat steps 1 through 4 for each additional configuration in Table 34 supported by the DUT.

6.3.3.5 Metrics (Pass/Fail Criteria)

1. For each configuration, the measured throughput MUST be equal to, or greater than the values listed in the table below.
 - a. If the DUT only supports a LAN interface speed below the listed pass/fail values in the table below the pass/fail requirement shall become the value listed in Table 9 for the corresponding LAN port speed. For example for a 1 Gbps Ethernet connection, the requirement for any metric exceeding 1 Gbps, such as Config 2, SHALL become 925 Mbps as defined in Table 9.

Table 35: 802.11ax Peak Performance Throughput Requirements

Wi-Fi Configuration	Downlink Throughput Requirement (NOTE 1) (Mbps)	Uplink Throughput Requirement (NOTE 1) (Mbps)
Config 1 802.11ax, 2.4 GHz, NSS = 2, BW = 40 MHz	300	300
Config 2	1100	1100

802.11ax, 5 GHz, NSS = 2, BW = 160 MHz		
Config 3 802.11ax, 5 GHz, NSS = 4, BW = 160 MHz	2400	2400
Config 4 802.11ax, 5 GHz, NSS = 8, BW = 160 MHz	4800	4800

6.4 Multiple STAs Performance

6.4.1 Multiple STAs Performance Test

6.4.1.1 Introduction

Multiple STAs performance test intends to measure the performance of Wi-Fi device connected with multiple STAs simultaneously. To simulate a circumstance of real environment, various levels of signals reflecting various distance between Wi-Fi device and STA are considered in the test.

This test SHALL be OPTIONAL for the test plan.

6.4.1.2 Setup

The same test setup shown in Figure 12 SHALL be used. Note the STA in Figure 12 is duplicated by 9 times in this test.

1. A total of 9 STAs are engaged in the test. Three STAs are located at the close distance to the DUT. Three STAs are located at the medium distance to the DUT. The rest of the STAs are located at the far distance to the DUT. The close/medium/far distances are emulated by adding additional attenuation for the signals as defined in Table 8.
2. A Traffic Generator/Analyzer, sending the corresponding Ethernet packets to each STA, connects to the LAN interface (e.g., GE port) of the DUT.
3. TCP connection SHALL be used for Ethernet packet transmission in the test.
4. STAs shall be configured to use 2 spatial streams.

6.4.1.3 DUT Configuration

The test SHALL run under the following configuration:

1. General configuration for DUT/STA working mode, bandwidth and number of RF chains:

Table 36: DUT configuration for Multiple Association / Disassociation Stability Test

Wi-Fi configuration	Bandwidth (MHz)
802.11n (NSS=2)	20
802.11ac (NSS=2)	80
802.11ax (2.4 GHz, NSS=2)	20
802.11ax	80

(5 GHz, NSS=2)	
802.11ax (6 GHz, NSS=2)	160

2. The general configuration SHALL be tested if the configuration is applicable for DUT.

6.4.1.4 Procedures

1. Configure DUT working mode as 802.11n, operating frequency band as 2.4 GHz with default configuration.
2. Enable the radios on the STAs with the close distance. Allow STA to associate with the DUT.
3. Measure the downlink TCP throughput to each STA, using a test time of 120 seconds. Calculate the summation of downlink TCP throughput of the three STA in close distance. Record the result as "Throughput_C_DL". Wait for 10 seconds. Measure the uplink TCP throughput to each STA, using a test time of 120 seconds. Calculate the summation uplink TCP throughput of the three STA in close distance. Record the result as "Throughput_C_UL".
4. Enable the radios on the STAs with the medium distance. Allow STA to associate with the DUT. Measure the downlink TCP throughput to each STA, using a test time of 120 seconds. Calculate the summation of downlink TCP throughput of all STA (three STA in close distance and the three STA in medium distance). Record the result as "Throughput_CM_DL". Wait for 10 seconds. Measure the uplink TCP throughput to each STA, using a test time of 120 seconds. Calculate the summation of uplink TCP throughput of all STA (the three STA in close distance and the three STA in medium distance). Record the result as "Throughput_SM_UL".
5. Enable the radios on the STAs with the far distance. Allow STA to associate with the DUT. Measure the downlink TCP throughput to each STA, using a test time of 120 seconds. Calculate the summation of all STA (downlink TCP throughput of the three STA in close distance, the three STA in medium distance and the three STA in far distance). Record the result as "Throughput_CMF_DL". Wait for 10 seconds. Measure the uplink TCP throughput to each STA, using a test time of 120 seconds. Calculate the summation of uplink TCP throughput of all STA (the three STA in close distance, the three STA in medium distance and the three STA in far distance). Record the result as "Throughput_CMF_UL".
6. Repeat step 2-5 for all supported configurations as defined in Table 36.

Note 1: The test result MAY be slightly affected by the capability of Peer STA. The test MAY be conducted with multiple peer STAs with chipsets from different vendors. The calculated average throughput then is averaged again in the dimension of chipset.

6.4.1.5 Metrics (Pass/Fail Criteria)

In order to pass the test case, the recorded results SHALL meet the Pass/Fail Criteria, described as following:

- a) Throughput of the Peer STAs SHALL satisfy the requirement in Table 37

Table 37: Throughput requirement of Multiple STAs Performance Test

Wi-Fi configuration	Bandwidth (MHz)	Throughput_C (Mbps)		Throughput_CM (Mbps)		Throughput_CMF (Mbps)	
		DL	UL	DL	UL	DL	UL
802.11n (NSS=2)	20	70	70	60	60	50	50
802.11ac (NSS=2)	80	500	450	500	250	400	200

802.11ax (2.4 GHz, NSS=2)	20	140	140	120	120	100	100
802.11ax (5 GHz, NSS=2)	80	680	600	600	250	500	200
802.11ax (6 GHz, NSS=2)	160	1360	1200	1200	500	1000	400

6.4.2 Multiple Association/Disassociation Stability Test

6.4.2.1 Introduction

Multiple association/disassociation stability measures the stability of Wi-Fi device under a dynamic environment with frequent change of connection status.

This test SHALL be MANDATORY for the test plan.

6.4.2.2 Setup

1. The test setup (shown in Figure 7) SHALL be located in the anechoic shielded chamber (see section 5.2.1 and 5.2.2).
2. 16 peer STAs SHALL be connected to the dedicated operating frequency band (2.4 GHz or 5 GHz) and the STA and DUT placed at distance between them of the AAV as calibrated in section 5.2.5 based on the profile under test. The test is only conducted for one operating frequency band in each test cycle.
3. UDP connection SHALL be used for Ethernet packet transmission in the test.

6.4.2.3 DUT Configuration

The test SHALL run under the following configuration:

1. General configuration for DUT/STA working mode, bandwidth, and number of RF chains:

Table 38: DUT configuration for Multiple Association / Disassociation Stability Test

Wi-Fi configuration	Bandwidth (MHz)
802.11n (NSS=2)	20
802.11ac (NSS=2)	80
802.11ax (2.4 GHz, NSS=2)	20
802.11ax (5 GHz, NSS=2)	80

2. The general configuration SHALL be tested if the configuration is applicable for DUT.

6.4.2.4 Procedures

1. Configure the working mode of DUT as 802.11n, operating frequency as 2.4 GHz with the default configuration.
2. 8 STAs are picked for sending/receiving packet while the other 8 STAs are picked to do association/re-association process during the test. Establish the LAN connection and allow STA to associate with the DUT. Enable downlink UDP flow (4 Mbps @2.4 GHz and 8 Mbps @5 GHz) from DUT to each STA.
3. Start monitoring the traffic flow of each STA.
4. Let traffic run for 30 seconds to ensure throughput stability when all stations are connected.
5. Disassociate the stations that are not configured to send traffic.
6. Wait for 30 seconds.
7. Re-associate the STAs simultaneously.
8. Wait for 30 seconds.
9. Stop recording throughput stats and stop the UDP traffic.
10. .Configure the working mode of DUT as 802.11ac, operating frequency band as 5 GHz and the channel bandwidth to 80 MHz, respectively. Wait for 10 seconds, repeat Steps 2-9.
11. Configure the working mode of DUT as 802.11ax over 2.4 GHz, operating frequency band as 5 GHz and the channel bandwidth to 20 MHz, respectively. Wait for 10 seconds, repeat Steps 2-9.
12. Configure the working mode of DUT as 802.11ax over 5 GHz, operating frequency band as 5 GHz and the channel bandwidth to 80 MHz, respectively. Wait for 10 seconds, repeat Steps 2-9.

Note: The test result MAY be slightly affected by the capability of Peer STA. The test MAY be conducted with multiple peer STAs with chipsets from different vendors.

6.4.2.5 Metrics (Pass/Fail Criteria)

In order to pass the test case, the recorded results SHALL meet the Pass/Fail Criteria, described as following:

1. For the total samples gathered during the duration of the test, the throughput must be at least 99% of the configured rate for each STA.
2. For the total samples gathered during the duration of the test, the packet loss rate MUST be less than 0.01%.for each STA.

6.4.3 Downlink MU-MIMO Performance Test

6.4.3.1 Introduction

Downlink MU-MIMO Performance Test verifies the performance of Wi-Fi device when Downlink MU-MIMO is applied. This best represents a typical deployment, where stations may only support 1x1 or 2x2 RF chain configurations. The test is only applicable to the Wi-Fi device supporting the 802.11ac/ax. Downlink MU-MIMO capability is also sometimes referred to as 802.11ac Wave 2.

This test SHALL be conditionally MANDATORY for the test plan. If the DUT supports Downlink MU-MIMO with at least 3 spatial streams (NSS=3) for each band to be tested, the test is required. Otherwise, the test is not required.

6.4.3.2 Setup

1. The test setup (see Figure 9) SHALL be located in the anechoic shielded chamber (see section 5.2.1 and 5.2.2).

2. The DUT and engaged peer STAs SHALL support 802.11ac or 802.11ax and MU-MIMO. One STA (STA 1) supports a maximum two spatial streams while two STAs (STA 2 and STA 3) support only one spatial stream.
3. All STAs and DUT are placed at the AAV as calibrated in section 5.2.5 based on the profile under test and are placed at different angles relative to the DUT, according to the requirements in section 5.2.4.
4. A Traffic Generator/Analyzer, sending the Ethernet packet to each peer STA, connects to the LAN interface of the DUT.
5. TCP connection SHALL be used for Ethernet packet transmission in the test.

6.4.3.3 DUT Configuration

The test SHALL run under the default configuration and SHALL ensure the following configuration settings are also applied:

- a) 802.11ac Downlink MU-MIMO *enable*
- b) 802.11ax 2.4 GHz Downlink MU-MIMO *enable*, OFDMA *disabled*
- c) 802.11ax 5 GHz Downlink MU-MIMO *enable*, OFDMA *disabled*

6.4.3.4 Procedures

1. Establish the setup by using the default configuration as detailed above.
2. Associate STA 1 with DUT. Establish the LAN connection and wait for 10 seconds.
3. Measure the downlink TCP throughput to STA1, using a test time of 120 seconds. Record this value as STA1_throughput_1.
4. Disassociate STA1. Wait for 10 seconds. Associate STA 2 with DUT. Wait for 10 seconds. Measure the downlink TCP throughput to STA2, using a test time of 120 seconds. Record this value as STA2_throughput_1.
5. Disassociate STA 2. Wait for 10 seconds. Associate STA 3 with DUT. Wait for 10 seconds. Measure the downlink TCP throughput to STA 3, using a test time of 120 seconds. Record this value as STA3_throughput_1.
6. Associate STA 1 and STA 2 with the DUT (STA 3 remains associated). Simultaneously measure the downlink TCP throughput to all STA, using a test time of 120 seconds. Record these values as STA1_throughput_2, STA2_throughput_2 and STA3_throughput_2.
7. Disable DL MU-MIMO and wait for 10 seconds. Simultaneously measure the downlink TCP throughput to each STA, using a test time of 120 seconds. Record these values as STA1_throughput_3, STA2_throughput_3 and STA3_throughput_3. If the DUT does not support this operation, this step and the associated test metric SHALL NOT apply.
8. Repeat steps 1 through 7 for each DUT configuration listed above in section 6.4.3.3.

6.4.3.5 Metrics (Pass/Fail Criteria)

In order to pass the test case, the recorded results SHALL meet the Pass/Fail Criteria, described as follows:

1. The sum of STA1_throughput_2, STA2_throughput_2, and STA3_throughput_2 SHALL be at least 45% of the sum of STA1_throughput_1, STA2_throughput_1, and STA3_throughput_1.
2. The sum of STA1_throughput_2, STA2_throughput_2, and STA3_throughput_2 SHALL be greater than the sum of STA1_throughput_3, STA2_throughput_3, and STA3_throughput_3. This test metric SHALL only apply to the DUT that supports the configuration to disable DL MU-MIMO.
3. The sum of STA1_throughput_3 + STA2_throughput_3 + STA3_throughput_3 MUST be at least 50Mbps.

6.5 Stability/Robustness

6.5.1 Long Term Stability Test

6.5.1.1 Introduction

Long term stability measures the stability performance of Wi-Fi device under stresses that would typically been seen under heavy user load, such as watching multiple 4k video streams. Throughput and connection availability are continuously monitored over a period of 4 hours, during which time, the performance must remain steady. Testing is conducted in multiple bands (2.4 GHz, 5 GHz and optionally 6 GHz) simultaneously.

This test SHALL be MANDATORY for the test plan.

6.5.1.2 Setup

1. The test setup (See Figure 6) SHALL be located in the anechoic shielded chamber (see section 5.2.1 and 5.2.2).
2. The STAs and DUT are placed at the AAV as calibrated in section 5.2.5 based on the profile under test.
3. A total of 4 STAs SHALL be used during the test, with 2 STAs connecting within the 2.4 GHz band and 2 STAs connecting within the 5 GHz band.
4. If 6 GHz band is support, there will be 2 additional STAs on the 6 GHz band.
5. One STA in each band SHALL be used to perform traffic performance measurements, while the other STA in the band SHALL be used to periodically associate and disassociate from the DUT.
6. A Traffic Generator/Analyzer, establishing the Ethernet packets transmission to the STA (allocated to receive packets), connects to the LAN interface (e.g., GE port) of the DUT.
7. UDP connections, operating at a fixed bitrate SHALL be used to measure the performance of the DUT.

6.5.1.3 DUT Configuration

The test SHALL run under the following configurations:

1. 802.11n and 802.11ac
2. 802.11ax 2.4 GHz, 802.11ax 5 GHz and 802.11ax 6 GHz (if supported).

If the DUT does not include multiple radios (i.e., the DUT does not support either the 2.4, 5 or 6 GHz band), the test SHALL be run with only the supported bands in operation.

6.5.1.4 Procedures

1. Configure the DUT for the first operating configuration described above.
2. Configure the 2 STAs connecting to the 2.4 GHz band to associate with the DUT.
3. Configure the 2 STAs connecting to the 5 GHz band to associate with the DUT. For second configuration configure the 2 STAs connecting to the 6 GHz band to associate with the DUT.
4. Wait for 60 seconds for the system to reach a steady state.
5. Configure two downlink UDP throughput measurements to run for 15 minutes each using a bit rate of 50 Mbps through one 2.4 GHz STA and one 5 GHz STA and for second configuration the 6 GHz STA. While this throughput measurement is running perform the following actions:
 - i. Wait 5 minutes

- ii. Toggle the association state of the second STA in each band (i.e., if the STA is currently associated to the DUT, cause it to disassociate; or if it is disassociated, cause it to associate).
6. Record the number of lost UDP packets for each downlink measurement, recording the measurement as `PACKET_LOSS_[24,5 or 6]_GHZ_INTERVAL_n`, where the band is indicated as 2.4,5 or 6 GHz and n represents the n'th measurement interval. Calculate the `PACKET_LOSS_RATIO_[24, 5 or 6]_GHZ_INTERVAL_n` as the number of lost packets divided by the total number of packets transmitted.
7. Repeat steps 4 and 6 for a total of 16 measurement intervals (4 hours of testing).
8. Repeat steps 1 through 7 for each DUT configuration defined above.

6.5.1.5 Metrics (Pass/Fail Criteria)

In order to pass the test case, the recorded results SHALL meet the Pass/Fail Criteria, described as following:

1. For each measurement interval, the packet loss ratio SHALL be less than or equal to 1E-4.

6.5.2 AP Coexistence Test

6.5.2.1 Introduction

AP coexistence test verifies Wi-Fi device performance with existence of alien AP.

This test SHALL be MANDATORY for the test plan.

Note: This test case implements a simplified scenario where the alien network presents a 50% utilization/contention with the DUT.

Note: When testing within the 5 GHz working frequency, 40 MHz channel bandwidths are utilized to avoid the usage of DFS channels.

6.5.2.2 Setup

1. The test setup (shown in Figure 14) SHALL be located in the anechoic shielded chambers (see section 5.2.1 and 5.2.2).
2. The ATTN A value shall be set to the medium value in Table 8 matching the band of the profile under test.
3. The STAs and DUT are placed at the AAV as calibrated in section 5.2.5 based on the profile under test.
4. A host sends/receives the Ethernet packets/IP packets to DUT. The Peer STA receives/sends the Wi-Fi packets from/to the DUT through air interface.
5. The host SHALL send the Ethernet packets/IP packets at the maximum rate which the DUT can achieve.
6. A set of Wi-Fi interfaces/radios, supporting the same Wi-Fi standard (802.11n/802.11ac/802.11ax), are used to generate the alien network interference, per the configurations described in Table 40. The QoS settings on the alien network SHALL match those on the DUT.
7. TCP connection SHALL be used for Ethernet packet transmission in the test.
8. The Alien AP SHALL be the same manufacturer, model, and firmware version of the DUT and SHALL be configured identically to the DUT except for the settings specified in Table 40 and the SSID that SHALL be set to "BBF_Wi-Fi_Perf_Test_Alien".
9. The Alien AP SHALL have the same orientation as the DUT. (For example if the DUT uses a mounting bracket to stand upright, the Alien AP shall use a bracket to have the same orientation and not lie flat).

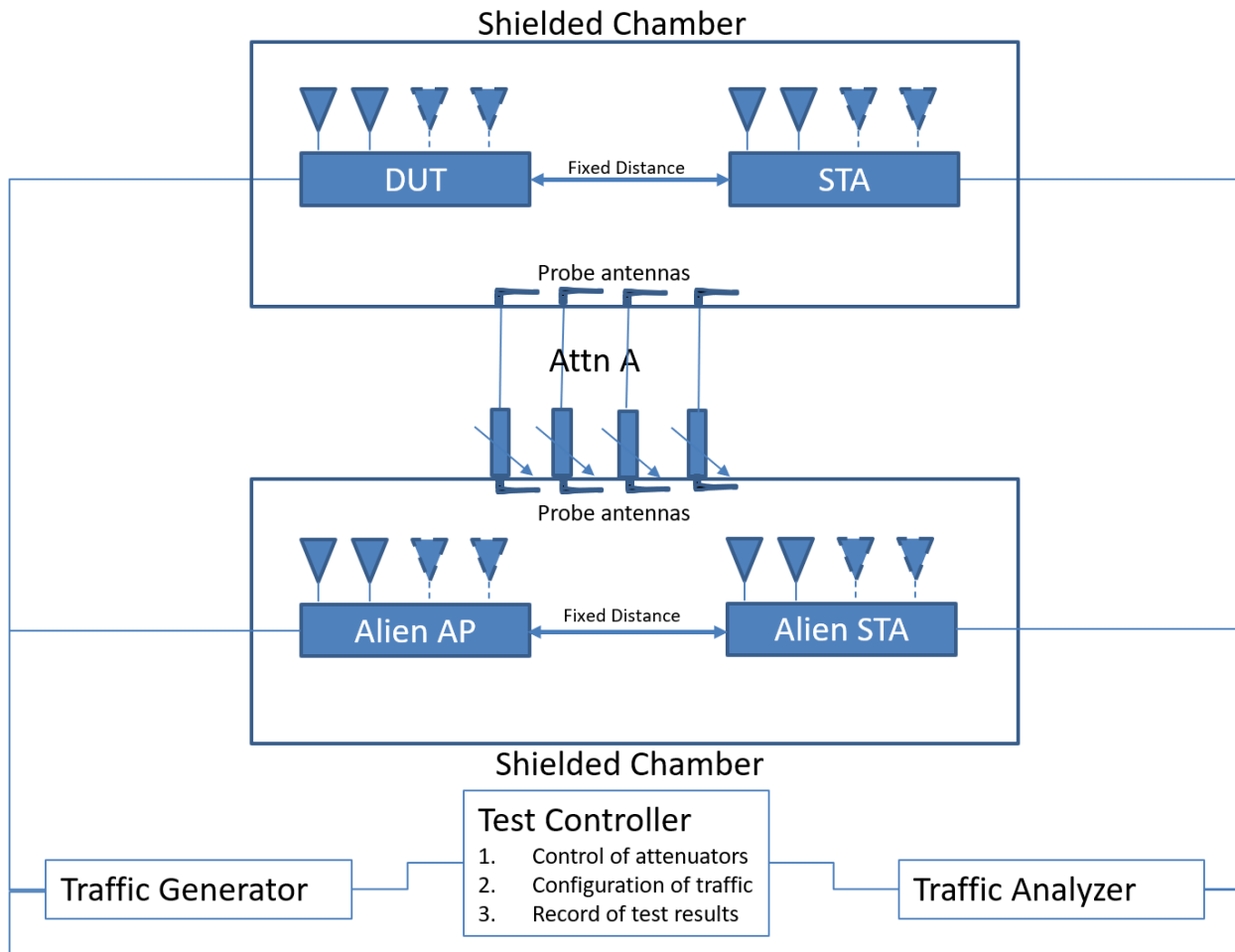


Figure 14: Test Setup of AP Coexistence Test

Note: Only 1 antenna is needed to be in use for this specific testing scenario between the chambers.

6.5.2.3 DUT Configuration

The test SHALL run under the following configuration:

1. General configuration for DUT/STA working mode, bandwidth and number of RF chains:

Table 39: General configuration for AP coexistence test

Wi-Fi configuration	Bandwidth (MHz)
802.11n (NSS=2)	20
802.11ac (NSS=2)	80
802.11ax (2.4 GHz, NSS=2)	20
802.11ax (5 GHz, NSS=2)	80

802.11ax (6GHz, NSS=2)	160
Note: The channel configuration of alien network MAY use either NSS = 1 or NSS = 2.	

Note: The general configuration SHALL be tested if the configuration is applicable for DUT.

- The alien network SHALL be set to different configurations:

Table 40: Channel configuration in the test

Working frequency	Channel configuration (DUT+peer STA) (Note 1)	Channel configuration (Alien network)		
		Same channel	Overlapping channel	Adjoining channel
2.4 GHz	6	6	7	11
5 GHz	36(Note 3)	36	36 (Note 2)	44 (Note 3)
6 GHz	47	47	55 (Note 4)	79
Notes: <ol style="list-style-type: none"> If channels other than the default channels are used, the separation of the center frequencies of the channels should be the same as the separation of the center frequencies as defined using the default channels, and the bandwidths should be the same as in the default test case. This intends to emulate the effects of an overlapped channel (5 GHz alien configuration is set to use a 40 MHz channel, while the DUT continues to use an 80 MHz channel). When testing the adjoining channel case for the 5 GHz working frequency, two 40 MHz channels SHALL be used to avoid the usage of DFS channels. This intends to emulate the effects of an overlapped channel (6 GHz alien configuration is set to use a 80 MHz channel, while the DUT continues to use a 160 MHz channel). 				

6.5.2.4 Procedure

- Configure the working mode of DUT to 802.11n, operating frequency band to 2.4 GHz with default configuration.
- Turn off the DUT and the peer STA.
- Turn on the alien AP and alien STA, allow the alien STA to associate with the alien AP, then wait for 10 seconds.
- Measure the downlink TCP throughput to the alien STA, using a test time of 120 seconds. Record this measurement as THROUGHPUT_SHORT_ALIEN.
- If testing the 5 GHz working frequency, configure the alien AP to use the 40 MHz channel bandwidth, measure the downlink TCP throughput to alien STA, using a test time of 120 seconds. Record this measurement as THROUGHPUT_SHORT_ALIEN_40MHz. This value is used to calculate the performance deduction only for the adjoining channel case; for all other tests, the DUT is configured to use the 80 MHz channel bandwidth.
- If testing the 6 GHz working frequency, configure the alien AP to use the 80 MHz channel bandwidth, measure the downlink TCP throughput to alien STA, using a test time of 120 seconds. Record this measurement as THROUGHPUT_SHORT_ALIEN_80MHz. This value is used to calculate the performance deduction only for the adjoining channel case; for all other tests, the DUT is configured to use the 80 MHz channel bandwidth.
- The channel of alien network SHALL be set to the same channel as DUT.
- Turn off the alien AP and alien STA, turn on the DUT and peer STA.

9. Allow peer STA to associate with the DUT.
10. Wait for 10 seconds. Measure the downlink TCP throughput to peer STA, using a test time of 120 seconds. Record this measurement as THROUGHPUT_SHORT_DUT.
11. If testing the 5 GHz working frequency, configure the DUT to use the 40 MHz channel bandwidth, measure the downlink TCP throughput to peer STA, using a test time of 120 seconds. Record this measurement as THROUGHPUT_SHORT_DUT_40MHz. Note, this value is used to calculate the performance deduction only for the adjoining channel case; for all other tests, the DUT is configured to use the 80 MHz channel bandwidth.
12. Enable the alien network radios. The alien network SHALL be configured according to Table 40. The alien network will transmit beacon frames according to the default configuration settings of 5.3.3.
13. Wait for 10 seconds. Measure the downlink TCP throughput to peer STA, using a test time of 120 seconds. Record this measurement as THROUGHPUT_SHORT_DUT_1.
14. Configure the alien network to transmit a UDP data stream at 40% of the measurement THROUGHPUT_SHORT_ALIEN or THROUGHPUT_SHORT_ALIEN_40MHz or THROUGHPUT_SHORT_ALIEN_80MHz, depending on the configuration of the alien AP bandwidth (160MHz, 80 MHz or 40 MHz).
15. Wait for 10 seconds. Measure the downlink TCP throughput to peer STA, using a test time of 120 seconds. Record this measurement as THROUGHPUT_SHORT_DUT_2.
16. Change the channel configuration of alien AP according to Table 40 until all the configurations have been tested. Stop the packet transmission for alien network.
17. Shut down the radios on the alien network.
18. Repeat steps 2 to 18 for each additional configuration listed in Table 39 above.

6.5.2.5 Metrics (Pass/Fail Criteria)

In order to pass the test case, the recorded results SHALL meet the Pass/Fail Criteria, described as following:

1. The average throughput measured SHALL satisfy the requirements in Table 41:

Table 41 Pass/Fail criteria for AP coexistence test

Wi-Fi configuration	Bandwidth (MHz)	Throughput requirement referred to the No-Alien-device				
		No alien device	Alien AP turned on	Alien network working (same channel)	Alien network working (overlapping channel)	Alien network working (adjoining channel)
802.11n (NSS=2)	20	-	<5%	<60 %	<60%	<10%
802.11ac (NSS=2)	80	-	<5 %	<60 %	<60 %	<10 %
802.11ax (2.4 GHz, NSS=2)	20	-	<5%	<60%	<60%	<10%
802.11ax (5 GHz, NSS=2)	80	-	<5%	<60%	<60%	<10%
802.11ax (6 GHz, NSS=2)	160	-	<5%	<60%	<60%	<10%

Note: Percentage indicates the performance deduction referred to the case with no alien device turned on.

6.5.3 Automatic Channel Selection Test

6.5.3.1 Introduction

When operating in environments with multiple Wi-Fi based networks the AP may be able to more reliably select the channel with the lowest level of impairments from the adjacent networks compared to a less knowledgeable end user. The test verifies the DUT (AP) will select a Wi-Fi channel that is not presently utilized by other networks and will alter this channel on subsequent reboots, if the environment has changed (i.e., the channels utilized by the adjacent network has changed).

Note, this test is not intended to verify avoidance of radar or other non-Wi-Fi signals or usage of the same frequencies by other technology.

This test SHALL be OPTIONAL for the test plan.

6.5.3.2 Setup

1. The test setup (shown in Figure 14) SHALL be located in the anechoic shielded chamber (see section 5.2.1 and 5.2.2), using 2 stations and 1 additional AP.
2. The STA and DUTs are placed at the AAV as calibrated in section 5.2.5 based on the profile under test.
3. Configure the DUT to enable automatic channel selection for all its 2.4 GHz, 5 GHz and 6 GHz radios. Note, ensure these settings are persistently saved on the DUT.
4. Configure one station to enable only the 2.4 GHz band, use the SSID and password for the test network per section 5.3.2.
5. Configure the additional AP to use 2.4 GHz Wi-Fi channel 6, 20 MHz channel bandwidth, and the settings in Table 42 below.
6. Configure the second station to associate to the additional AP using the settings in Table 42 below.
7. The Ethernet traffic generator / analyzer is connected to the additional AP and STA.

Table 42: SSID configuration for adjacent network

Configuration Parameter	Value
SSID Name	BBF Adj Net
Enable SSID	True
Number of associated devices	32
Broadcast SSID	True
Enable WMM	True
Authentication Mode	WPA3
Encryption Mode	AES
WPA PreShareKey	<Defined by test agent>

6.5.3.3 DUT Configuration

The test SHALL run under the following configuration:

1. The DUT shall be tested with the latest supported 802.11 specification per band.

6.5.3.4 Procedures

1. Power off the DUT.
2. Allow the second station to associate to the additional AP.

3. Configure the Ethernet traffic generator to run a continuous TCP throughput measurement, causing the devices to continuously transmit over the Wireless link between the second STA and AP.
4. Power on the DUT and allow the first station to associate with the DUT.
5. Record the channel used by the DUT.
6. Repeat steps 1 through 5, with the additional AP configured to use 2.4 GHz channels 1 and 11.
7. Repeat steps 1 through 5, with the additional AP configured to use 2.4 GHz channel 1 and 40 MHz bandwidth.
8. Repeat steps 1 through 5, using the 5 GHz band, with the additional AP configured to channels 42, 58, 106, and 122. If the DUT AP does not support the additional AP channel, that channel SHALL be skipped. The additional AP SHALL be configured to use a channel bandwidth of 80 MHz.
9. Repeat steps 1 through 5, using the 6 GHz band, with the additional AP configured to channels 47, 111, 143 and 207. The additional AP SHALL be configured to use a channel bandwidth of 160 MHz.

6.5.3.5 Metrics (Pass/Fail Criteria)

In order to pass the test case, the recorded results SHALL meet the Pass/Fail Criteria, described as following:

1. The DUT SHALL select a channel that is not the same as the channel the Additional AP is operating on and the selected channel SHALL not overlap with the channel the Additional AP is operating on. If the DUT selects the same, or an overlapping channel, the test point SHALL be considered a failure.

Table 43: Automatic Channel Selection Test Requirements

Test Point	Additional AP Operating Band and Channel	Channel Selected by the DUT
1	2.4 GHz Channel 6, BW = 20 MHz	
2	2.4 GHz Channel 11, BW = 20 MHz	
3	2.4 GHz Channel 1, BW = 20 MHz	
4	2.4 GHz Channel 1, BW = 40 MHz	
5	5 GHz Channel 42, BW = 80 MHz	
6	5 GHz Channel 58, BW = 80 MHz	
7	5 GHz Channel 106, BW = 80 MHz	
8	5 GHz Channel 157, BW = 80 MHz	
9	6 GHz Channel 47, BW = 160 MHz	
10	6 GHz Channel 111, BW = 160 MHz	
11	6 GHz Channel 143, BW = 160 MHz	
12	6 GHz Channel 207, BW = 160 MHz	
<p>Note: 5 GHz channel numbers are specified as 80 MHz bandwidth channel numbers. If the DUT does not support the 80 MHz wide channel or uses the 20 MHz wide channel numbers, the DUT SHALL not overlap with the 80MHz channel utilized by the adjunct network.</p>		

6.6 Mesh/Extender

6.6.1 Mesh Wi-Fi Extender Throughput Performance Test

6.6.1.1 Introduction

This test case measures the throughput performance of a mesh Wi-Fi system, where the Wi-Fi Extender is at different emulated distances from the Root AP. The DUT is considered to be the combination of a “Root AP” and a “Wi-Fi Extender.” The “Root AP” is defined as the AP devices connected to the wired network connection of the traffic generator and analyzer, while the “Wi-Fi Extender” has only RF connections to both the “Root AP” and the STA. During this test, the STA is only connected to the “Wi-Fi Extender.” The Wi-Fi connection between the “Root AP” and “Wi-Fi Extender” is configured to enable all supported radios and protocols, allowing the two devices to adapt the Wi-Fi connection according to their internal logic. The STA’s RF connection is configured to a specific operating mode. The back-haul link between “Root AP” and the “Wi-Fi Extender” is expected to be at least NSS=2 or better in performance for this test.

The attenuation values in this setup are based the AAV calibration values from section 5.2.5

This test SHALL be OPTIONAL for the test plan.

6.6.1.2 Setup

1. The test setup shown in Figure 4: Wi-Fi Mesh Multiple Chamber Implementation SHALL be used for this test.
2. The “Root AP” SHALL be placed in Shielded Chamber 1 and connected to the traffic generator.
3. The “Wi-Fi Extender” SHALL be placed in Shielded Chamber 2.
4. The Attn A set SHALL be configured to 5GHz AAV calibration value from section 5.2.5 plus 30dB
5. The Attn B set SHALL be set to 0dB.
6. The Attn C set SHALL be set to its maximum value to ensure the STA cannot talk to the Root AP.
7. The Attn D, Attn E and Attn F set SHALL be configured to maximum allowed dB to ensure no secondary path between chambers.
8. The Traffic Generator/Analyzer, capable of sending the Ethernet packets, SHALL be connected to the LAN interface (e.g., GE port) of the “Root AP” and the STA.
9. The Traffic Generator/Analyzer SHALL be configured to measure the throughput using TCP sessions.

6.6.1.3 DUT Configuration

The test SHALL be run with the STA configured for each of the operating modes listed in [Table 44](#) below. For each configuration, a set of attenuation values for Attn A shall be measured. The different operating modes may expose trade-offs due to how the DUT manages it’s backhaul. For instance, if backhaul is on 2.4GHz, and STA is also talking to AP on 2.4GHz, that channel will be very congested.

In the table below, the Attenuation values are relative to the AVV setting as determined from the calibration as defined in section 5.2.5 on 5GHz channel. Assuming a 20db transmitter, this should translate to a 5GHz RSSI of around -54, and -69.

Table 44: DUT configuration for Wi-Fi Extender Throughput Performance Test

Wi-Fi Configuration	Configuration Description	Attn A Values (dB)
Config 1	802.11n, NSS = 2, BW = 20 MHz	24,39

Config 2	802.11ac, NSS = 2, BW = 80 MHz	24,39
Config 3	802.11ax 2.4 GHz, NSS = 2, BW = 20 MHz	24,39
Config 4	802.11ax 5 GHz, NSS = 2, BW = 80 MHz	24,39
Config 5	802.11ax 6 GHz, NSS= 2, BW = 160 MHz	24,39

6.6.1.4 Procedures

1. Configure the STA to operate in the first configuration mode described in **Table 44**. Allow station to use any channel on the selected band in order to allow DUT to determine best channel to use for STA and backhaul connectivity.
2. Configure Attn A for the first value described in **Table 44**.
3. Wait 30 seconds to let DUT mesh establish.
4. Establish the LAN connection and allow STA to associate with the DUT (Wi-Fi Extender).
5. Measure the downlink TCP throughput to the STA, using a test time of 120 seconds.
6. Measure the uplink TCP throughput to the STA, using a test time of 120 seconds.
7. Repeat steps 2 through 6 for each attenuation value listed in **Table 44** for the configured operating mode.
8. Repeat steps 1 through 7 for each configuration from **Table 44** supported by the “Wi-Fi Extender.”

Note: The tester must ensure the STA is connected to the “Wi-Fi Extender” and not the “Root AP” through Attn C.

6.6.1.5 Metrics (Pass/Fail Criteria)

1. For each attenuation configuration, the STA MUST be able to associate to the “Wi-Fi Extender.”
2. For each attenuation configuration, the measured throughput MUST be equal to, or greater than the values listed in the tables below, for the required number of measurement points identified with the table.

Note: When developing the pass/fail metrics, it was taken into account that the control of the DUTs Wi-Fi backhaul type is not controlled (band and type), the numbers in the pass/fail requirements represent a number that gives a reasonable performance expectation of well performing Wi-Fi extender system.

Table 45: Pass/Fail requirements for Extender Wi-Fi Throughput Performance Test Configs 1-5

Config 1-4: 802.11n, 802.11ac, 802.11ax 2.4 GHz, 5 GHz and 6 GHz		
(4 out of 4 requirements MUST pass)		
Attn A Value (dB)	Wi-Fi Extender	
	Downlink Throughput Requirement (Mbps)	Uplink Throughput Requirement (Mbps)
24	160	160
39	80	80

6.6.2 Mesh 2-node Wi-Fi Extender Throughput Performance Test

6.6.2.1 Introduction

This test case measures the throughput performance of a mesh Wi-Fi system where the Wi-Fi Extenders are at different emulated distances from the Root AP and each other. The DUT is considered to be the combination of a “Root AP” and two “Wi-Fi Extenders.” The “Root AP” is defined as the AP device connected to the wired network connection of the traffic generator and analyzer, while the “Wi-Fi Extenders” have only RF connections to the “Root AP”, each other, and the STA. During this test, the STA is only connected to the “Wi-Fi Extender #2.” The Wi-Fi connections between the DUT devices are configured to factory suggested settings. The STA’s RF connection is configured to a specific operating mode. The backhaul links between “Root AP” and the “Wi-Fi Extenders” are expected to be at least NSS=2 or better in performance for this test.

The attenuation values in this setup are based on the AAV as calibrated in section 5.2.5 based on the profile under test.

This test SHALL be OPTIONAL for the test plan.

6.6.2.2 Setup

1. The test setup shown in Figure 4 “Wi-Fi Mesh Multiple Chamber Implementation” SHALL be used for this test.
2. The “Root AP” SHALL be placed in Shielded Chamber 1 and connected to the traffic generator.
3. The Wi-Fi Extender 1 SHALL be placed in Shielded Chamber 2.
4. The Wi-Fi Extender 2 SHALL be placed in Shielded Chamber 4.
5. The Attn A set SHALL be configured to 5 GHz AAV calibrated distance plus 30dB.
6. The Attn D set SHALL be configured to 5 GHz AAV calibrated distance plus 30dB.
7. The Attn E set SHALL be configured to 0db to allow STA to connect to “Wi-Fi Extender #2”.
8. The Attn B set SHALL be configured to maximum allowed dB to ensure the STA cannot talk to “Wi-Fi Extender #1”.
9. The Attn C set SHALL be configured to maximum allowed dB to ensure the STA cannot talk to the “Root AP”.
10. The Attn F set SHALL be configured to maximum allowed dB to ensure the “Wi-Fi Extender #2” cannot talk to the “Root AP”.
11. The Traffic Generator/Analyzer, capable of sending the Ethernet packets, SHALL be connected to the LAN interface (e.g., GE port) of the “Root AP” and the STA.
12. The Traffic Generator/Analyzer SHALL be configured to measure the throughput using TCP sessions.

6.6.2.3 DUT Configuration

The test SHALL be run with the STA configured for each of the operating modes listed in Table 46 below. The different operating modes may expose trade-offs due to how the DUT manages its backhaul. For instance, if backhaul is on 2.4 GHz, and STA is also talking to AP on 2.4 GHz, that channel will be very congested.

In the table below, the Attenuation values are relative to AAV calibration in section 5.2.5 on 5 GHz channel. Assuming a 20dBm transmitter, this should translate to a 5 GHz RSSI of around -60, -70, -80.

Table 46: DUT configuration for Wi-Fi Extender Throughput Performance Test

Wi-Fi Configuration	Configuration Description	Attn A and D Values(dB)
Config 1	802.11n, NSS = 2, BW = 20 MHz	24,39
Config 2	802.11ac, NSS = 2, BW = 80 MHz	24,39
Config 3	802.11ax 2.4 GHz, NSS = 2, BW = 20 MHz	24,39
Config 4	802.11ax 5 GHz, NSS = 2, BW = 80 MHz	24,39
Config 5	802.11ax 6 GHz, NSS = 2, BW = 160 MHz	24,39

6.6.2.4 Procedures

1. Configure the STA to operate in the first configuration mode described in Table 46. Allow station to use any channel on the selected band in order to allow DUT to determine best channel to use for STA and backhaul connectivity.
2. Configure Attn A and Attn D to the first value described in Table 46
3. Wait 30 seconds for DUT mesh to establish.
4. Establish the LAN connection and allow STA to associate with the DUT (Wi-Fi Extender #2).
5. Measure the downlink TCP throughput to the STA, using a test time of 120 seconds.
6. Measure the uplink TCP throughput to the STA, using a test time of 120 seconds.
7. Repeat steps 2 through 6 for each attenuation value listed in Table 46 for the configured operating mode.
8. Repeat steps 1 through 7 for each configuration from Table 46 supported by the “Wi-Fi Extenders.”

Note: The tester must ensure the STA is connected to the “Wi-Fi Extender 2” and not the “Root AP” or “Wi-Fi Extender 1”.

6.6.2.5 Metrics (Pass/Fail Criteria)

1. For each attenuation configuration, the STA MUST be able to associate to the “Wi-Fi Extender 2.”
2. For each attenuation configuration, the measured throughput MUST be equal to, or greater than the values listed in the tables below, for the required number of measurement points identified with the table.

Note: When developing the pass/fail metrics, it was taken into account that the control of the DUTs Wi-Fi backhaul type is not controlled (band and type), the numbers in the pass/fail requirements represent a number that gives a reasonable performance expectation of well performing Wi-Fi extender system.

Table 47: Pass/Fail requirements for Wi-Fi Extender Throughput Performance Test Configs 1-5

<p>Config 1-5: 802.11n, 802.11ac, 802.11ax 2.4 GHz, 5 GHz and 6 GHz (4 out of 4 requirements MUST pass)</p>	
	Wi-Fi Extender

Attn A and D Values (dB)	Downlink Throughput Requirement (Mbps)	Uplink Throughput Requirement (Mbps)
24	80	80
39	40	40

6.6.3 Roaming Time Test

6.6.3.1 Introduction

This test case measures the time it takes to roam between Wi-Fi connections of the “Root AP” and the “Wi-Fi Extender.” The “Root AP” is defined as the AP device connected to the wired network connection of the traffic generator and analyzer, while the “Wi-Fi Extender” has only RF connections to the both the “Root AP” and the STA. The roaming performance is defined as the duration of time the STA is disconnected from the network (not able to send or receive a packet from the Ethernet traffic generator / analyzer).

The attenuation values in this setup are based on the AAV calibration in section 5.2.5.

This test SHALL be OPTIONAL for the test plan.

6.6.3.2 Setup

1. The test setup shown in Figure 4 “Wi-Fi Mesh Multiple Chamber Implementation” SHALL be used for this test.
2. The “Root AP” SHALL be placed in Shielded Chamber 1 and connected to the traffic generator.
3. The “Wi-Fi Extender” SHALL be placed in Shielded Chamber 2.
4. The Attn A set SHALL be configured to the AAV from section 5.2.5 plus 30dB.
5. The Attn B set SHALL be configured to the AAV from section 5.2.5 plus 30dB.
6. The Attn C set SHALL be configured to the AAV from section 5.2.5 plus 70dB.
7. The Attn D, Attn E and Attn F set SHALL be configured to maximum allowed dB to ensure no secondary path between chambers.
8. The Traffic Generator/Analyzer, capable of sending the Ethernet packets, SHALL be connected to the LAN interface (e.g., GE port) of the “Root AP” and the STA.
9. The Ethernet traffic generator is configured to use iperf3, or an equivalent substitute, to transmit one stream of 1250-byte UDP packets at 1 Mbps. (100 packets per second) in both uplink and downlink directions. While the STA is (temporarily) disconnected, the UDP transmitter on the STA will probably be blocked. The downlink connection on Ethernet should NOT be blocked. The uplink traffic will help the DUT bridges/switches learn location of the STA, and the downlink traffic will be used to detect roam time. The downlink traffic MUST NOT “buffer” packets while Wi-Fi is disconnected for the roaming event.
10. The STA SHALL have 802.11v (BSS Transition Management Messages) enabled. The DUT MAY, but is not required, to support 802.11v.
11. If configurable, the STA SHALL have its roaming threshold set to -95 dBm. The roaming threshold determines the signal level at which the STA implements its own roaming behavior. Since the purpose of this test is to test the AP DUT (not the STA), this setting ensures that the STA will not take its own action until the signal level has become very low.

6.6.3.3 DUT Configuration

The test SHALL be run with the STA configured for each of the operating modes listed in Table 48: DUT configuration for Basic Roaming Performance Test below.

Table 48: DUT configuration for Basic Roaming Performance Test

Wi-Fi Configuration	Configuration Description
Config 1	802.11n, NSS = 2, BW = 20 MHz
Config 2	802.11ac, NSS = 2, BW = 80 MHz
Config 3	802.11ax 2.4 GHz, NSS = 2, BW = 20 MHz
Config 4	802.11ax 5 GHz, NSS = 2, BW = 80 MHz
Config 5	802.11ax 6 GHz, NSS = 2, BW= 160 MHz

6.6.3.4 Procedures

1. Configure the STA to operate in the first configuration mode described in Table 48. Allow station to use any channel on the selected band in order to allow DUT to determine best channel to use for STA and backhaul connectivity. STA should enable background scanning to allow STA to make roaming decisions. User may disable background scanning to emulate a ‘sticky’ STA in order to test DUT’s ability to force STA to roam. STA should enable power-save so that it can scan off-channel without undue packet loss. STA should NOT re-acquire DHCP upon roam, as long as it still has a valid lease.
2. Wait 30 seconds to allow the DUT Mesh to establish.
3. Establish the LAN connection and allow STA to associate with the DUT. Verify the STA is associated with the “Wi-Fi Extender.”
4. Enable the UDP transmission to/from Ethernet to STA.
5. Decrease the value of Attn C by 1 dB.
6. Increase the value of Attn B by 1 dB.
7. Wait 4 seconds.
8. Repeat steps 5 through 7 40 times, at which point Atten B should be at the AAV distance plus 70, and Atten C, should be at the AAV distance plus 30dB.
9. Stop the UDP transmission and record the number of UDP packets that were transmitted by the Ethernet and the number of UDP packets received by the STA. ^{Note 1}
10. Restart the UDP transmission to/from the STA.
11. Decrease the value of Attn B by 1 dB.
12. Decrease the value of Attn C by 1 dB.
13. Wait 4 seconds.
14. Repeat steps 11 through 13 40 times, at which point Atten C should be at the AAV distance plus 70, and Atten B, should be at the AAV distance plus 30dB.
15. Stop the UDP transmission and record the number of UDP packets that were transmitted by the Ethernet and the number of UDP packets received by the STA. ^{Note 1}
16. Repeat steps 1 through 15 for each configuration from Table 48 supported by the “Root AP” and “Wi-Fi Extender.”

Notes:

1. It is expected for there to be lost UDP packets (i.e., a difference in the total number of received and transmitted packets), caused by the roaming event. Each UDP packet represents an “interval” of time the STA was disconnected from the network and blocked from sending and receiving traffic.

6.6.3.5 Metrics (Pass/Fail Criteria)

1. For each roaming event (two per each Wi-Fi Configuration), the total number of dropped UDP packets (difference between received and transmitted packet counters) MUST be less than 200. Time for the roam to take place is for further study on feasibility.

7 Parameter Accuracies

This section tests the accuracy of parameters reported by the DUT. This is a stand-alone section; tests in this section are CONDITIONALLY MANDATORY and so either tests in this section are not run or they are all run in their entirety. These tests require that the parameter values can be read from the DUT by transmitting parameters defined in TR-181 over TR-369 from the DUT to the test controller. The TR-181 parameters that are read for RCPI, channel utilization and noise are, respectively, Device.WiFi.DataElements.Network.Device.{i}.Radio.{i}.BSS.{i}.STA.{i}.SignalStrength, Device.WiFi.DataElements.Network.Device.{i}.Radio.{i}.Utilization, and Device.WiFi.DataElements.Network.Device.{i}.Radio.{i}.Noise.

7.1.1 RCPI Accuracy

7.1.1.1 Introduction

The Receive Channel Power Indicator (RCPI) indicates the received radio signal power of the uplink from the associated STA to the access point, measured in dBm. This test measures the relative accuracy of RCPI as reported by the DUT.

RCPI represents the strength of the received signal, noise and interference power. RCPI is encoded per Table 9-154 of [IEEE 802.11-2016], with reported RCPI levels are in the range $-109.5 \leq P < 0$ dBm. An RCPI greater than 0 dBm is reported as 0 dBm. The difference between RCPI and Received Signal Strength Indicator (RSSI) is generally insignificant, however RSSI may be reported in varying formats and ranges. RSSI and RCPI, in dBm, should be equal if there is no external noise or interference.

This test provides a simplified measurement of the accuracy of relative changes in reported RCPI as the attenuation inserted between the DUT and the STA changes. As that attenuation is increased and decreased, the RCPI is recorded and compared to the change in the attenuation. This is a relative measurement only.

This test SHALL be CONDITIONALLY MANDATORY for the test plan, conditional on testing for parameter accuracies.

7.1.1.2 Setup

1. The test setup (shown in Figure 15) SHALL utilize a shielded chamber (see section 5.2.1 and 5.2.2).
2. The test uses either the single chamber implementation of Figure 2, or the multiple chamber implementation of Figure 3. The multiple chamber implementation shown in Figure 15 is recommended (but not mandated), since leakage may hinder attenuation accuracy in a single chamber with high attenuation values.
3. A Traffic Generator/Analyzer is connected to the station and DUT, capable of sending and receiving Ethernet frames in order to measure packet error rate. A UDP link SHALL be established between DUT and STA and traffic rate SHALL be set to 4 Mbps. The direction of data packets is from STA to DUT.
4. STA and DUT are placed at the AAV as calibrated in section 5.2.5 based on the profile under test. The attenuator SHALL support the attenuation values between 0 dB and 50 dB, in 10 dB steps.
- 5.

Transmit power of the STA is set as specified within Table 11, Table 12 and Table 13.

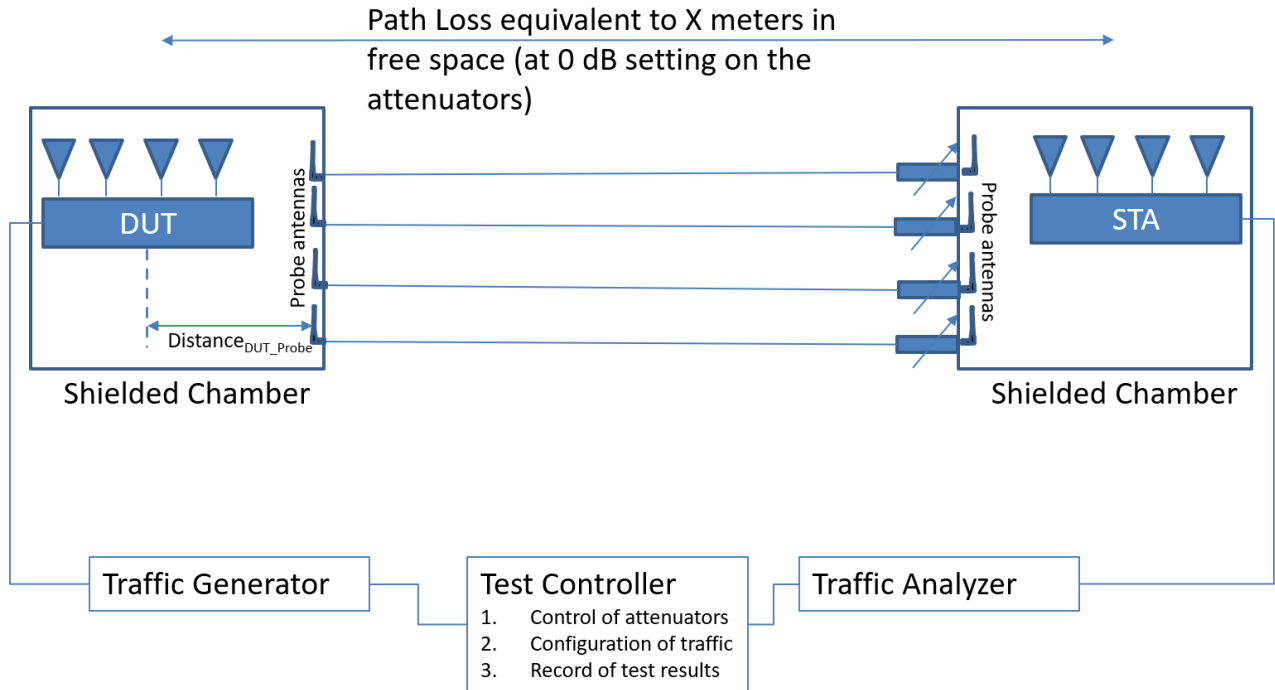


Figure 15: Test Setup for RCPI Accuracy

7.1.1.3 DUT Configuration

The test SHALL be run using each of the configurations from Table 49: Wi-Fi Test Configurations for RCPI accuracy below supported by the DUT. The test SHALL be conducted to the configurations that the DUT supports.

Table 49: Wi-Fi Test Configurations for RCPI accuracy

Test Configuration	Wi-Fi configuration
1	802.11n / 2.4 GHz / 20 MHz
2	802.11ac / 5 GHz / 80 MHz
3	802.11ax / 2.4 GHz / 20 MHz
4	802.11ax / 5 GHz / 80 MHz
5	802.11ax / 6 GHz / 160 MHz
NOTE: Configurations SHALL use a station supporting one spatial stream (NSS =1) only.	

Note: The test plan considers the common configurations to reduce the testing complexity.

7.1.1.4 Procedure

1. Configure the Traffic Generator to use a test data rate of 4 Mbps.
2. Allow STA to associate with the DUT.
3. Configure the attenuator(s) to 0 dB adjustment from the calibrated initial setting, based on the AAV calibration from section 5.2.5.

4. Enable packet generation from the STA to the DUT for 120 seconds.
5. If the packet error rate (PER) is less than 5%, then record the 0 dB RCPI value as reported by the DUT. Otherwise testing stops and the test is invalid.
6. Change the attenuator value to 5, 15, 25, 35, 45 and 55 dB. For each attenuator value, enable packet generation from the STA to the DUT for 1 minute, and after that if the packet error rate (PER) is less than 5%, then record the valid RCPI value reported by the DUT.

7.1.1.5 Metrics (Pass/Fail Criteria)

For each recorded valid RCPI value, the relative error = recorded valid RCPI value + attenuation - 0 dB RCPI value. If any such relative error has an absolute value greater than 2 dB then the test fails, otherwise passes.

7.1.2 Channel Utilization Accuracy

7.1.2.1 Introduction

The test provides a measurement of the accuracy of channel utilization as reported by the DUT. Several levels of traffic are injected to test different channel utilizations.

This test SHALL be CONDITIONALLY MANDATORY for the test plan, conditional on testing for parameter accuracies.

7.1.2.2 Setup

1. The test setup (shown in Figure 16) SHALL utilize a shielded chamber (see section 5.2.1 and 5.2.2).
2. A Traffic Generator/Analyzer is connected to the station and DUT, capable of sending and receiving Ethernet frames in order to measure packet error rate. A UDP link SHALL be established between DUT and STA and SHALL be transmitted from STA to DUT.
3. UDP connection SHALL be used for Ethernet packet transmission in the test.
4. Transmit power of the STA is set as specified within Table 11, Table 12 and Table 13.

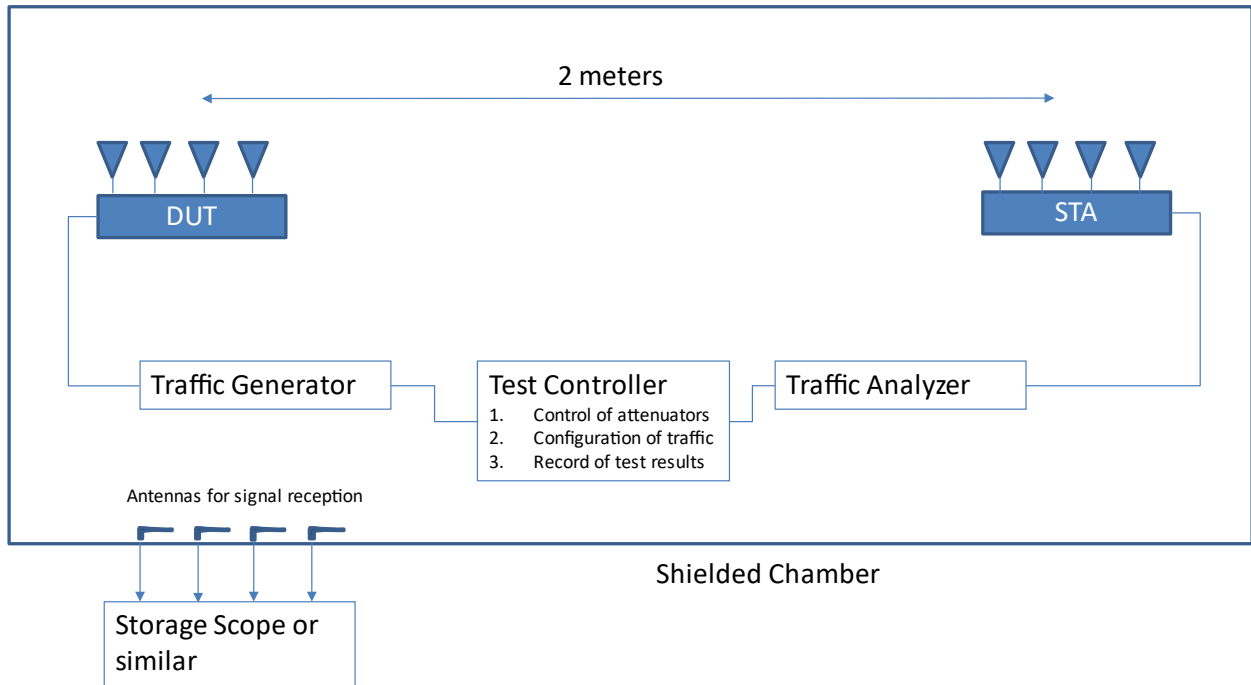


Figure 16: Test Setup for Channel Utilization Accuracy

7.1.2.3 DUT Configuration

The test SHALL be run using each of the configurations from Table 50 below supported by the DUT.

Table 50: Wi-Fi Test Configurations for Channel Utilization

Test Configuration	Wi-Fi configuration
1	802.11n / 2.4 GHz / 20 MHz
2	802.11ac / 5 GHz / 80 MHz
3	802.11ax / 2.4 GHz / 20 MHz
4	802.11ax / 5 GHz / 80 MHz
5	802.11ax / 6 GHz / 160 MHz
NOTE: Configurations SHALL use a station supporting one spatial stream (NSS =1) only.	

Note: The test plan considers the common configurations to reduce the testing complexity.

7.1.2.4 Procedure

1. Allow STA to associate with the DUT.
2. Configure the Traffic Generator to transmit at 75%, 50%, and 25% of the maximum throughput, which can be determined from the test in Section 6.2.2 Maximum Throughput Test. Run each of steps 3, 4 and 5 below for each traffic level.
3. Enable packet generation from the STA to the DUT for 120 seconds.

4. Record the percent channel utilization as reported by the DUT.
5. Record the actual percentage of airtime that has transmitting Wi-Fi traffic. Airtime traces can be recorded by storage oscilloscope coupled to an additional antenna located in the test chamber.

Note: Channel utilization also includes the airtime used by unassociated STAs and other BSSs; this is not tested above but could also be tested by injecting discontinuous noise.

Note: Channel utilization was recorded as reported by many APs in the field, and it never exceeded 90%.

7.1.2.5 Metrics (Pass/Fail Criteria)

For each recorded actual percentage of airtime, the relative error = percent channel utilization as reported by the DUT – the actual percentage of airtime that has transmitting Wi-Fi traffic. If any such relative error has an absolute value greater than 3% then the test fails, otherwise pass.

7.1.3 Noise Accuracy

7.1.3.1 Introduction

This test provides a measurement of the accuracy of noise levels as reported by the DUT. Several levels of noise are tested.

The reported noise is an indicator of the average radio noise plus interference power measured for the primary operating channel. Encoding of noise is as defined for ANPI in Section 11.11.9.4 of [802.11-2016].

This test SHALL be CONDITIONALLY MANDATORY for the test plan, conditional on testing for parameter accuracies.

7.1.3.2 Setup

1. The test setup (shown Figure 17) SHALL utilize a shielded chamber (see section 5.2.1 and 5.2.2).
2. The test uses either the single chamber implementation of Figure 2, or the multiple chamber implementation of Figure 3.
3. A Traffic Generator/Analyzer is connected to the station and DUT, capable of sending and receiving Ethernet frames in order to measure packet error rate. A UDP link SHALL be established between DUT and STA and traffic rate SHALL be set to 4 Mbps. The direction of data packets is from STA to DUT.
4. The transmit power of the STA SHALL NOT vary throughout the test.
5. A calibrated noise generator is connected and configured to inject known noise levels into the chamber. Noise is flat (white) at all frequencies across the configured channel.
6. Transmit power of the STA is set as specified within Tables 9, 10, and 11.

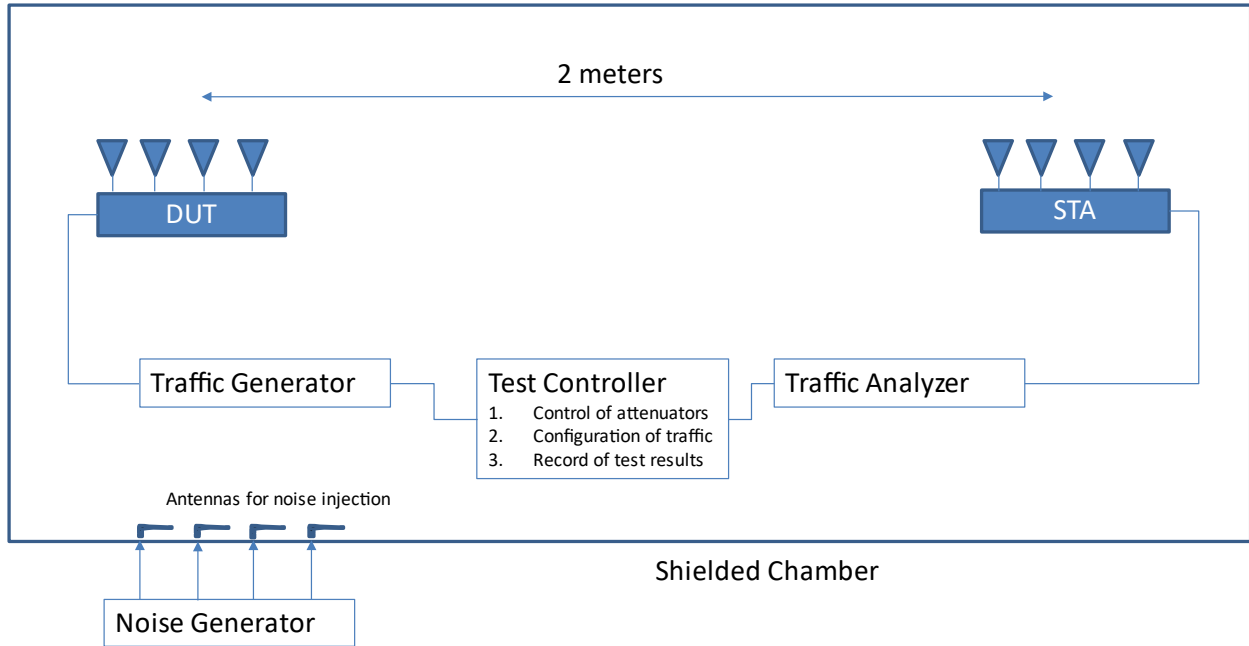


Figure 17: Test Setup for Noise Accuracy

7.1.3.3 DUT Configuration

The test SHALL be run using each of the configurations from Table 51 below supported by the DUT

Table 51: Wi-Fi Test Configurations for reported noise accuracy

Test Configuration	Wi-Fi configuration
1	802.11n / 2.4 GHz / 20 MHz
2	802.11ac / 5 GHz / 80 MHz
3	802.11ax / 2.4 GHz / 20 MHz
4	802.11ax / 5 GHz / 80 MHz
5	802.11ax / 6 GHz / 160 MHz
NOTE: Configurations SHALL use a station supporting one spatial stream (NSS =1) only.	

Note: The test plan considers the common configurations to reduce the testing complexity.

7.1.3.4 Procedure

1. Configure the Traffic Generator to use a test data rate of 4 Mbps.
2. Allow STA to associate with the DUT.
3. Inject noise at a level equal to TBD dBm/Hz into the chamber. Noise is flat (white) at all frequencies across the configured channel.
4. Enable packet generation from the STA to the DUT for 120 seconds.
5. If the packet error rate (PER) is less than 5%, then record the valid received noise power reported by the DUT. Otherwise testing stops.

6. Increase the noise level by 10 dB and repeat steps 4-6 until the PER exceeds 5% in step 6 and testing stops.

7.1.3.5 Metrics (Pass/Fail Criteria)

For each recorded valid received noise power, if the difference between the reported noise level and the actual injected noise level differs by more than 2 dB then the test fails, otherwise pass.

Appendix I. Instantiations of Test Setups

Appendix I provides instantiations of test setups as guidelines for execution of the test plan. The selection of the test equipment is out of scope of this document.

I.1 Test setup by using IP packet through TCP or UDP

If TCP/UDP flow is required in the test, the Packet Generator/Analyzer SHALL be IP traffic generator/analyzer. Performance statistics of TCP flow SHOULD be conducted from the TCP flow sender (packet generator) while a performance statistics of UDP flow as a report SHOULD be sent from the receiver (packet analyzer) to sender (packet generator).

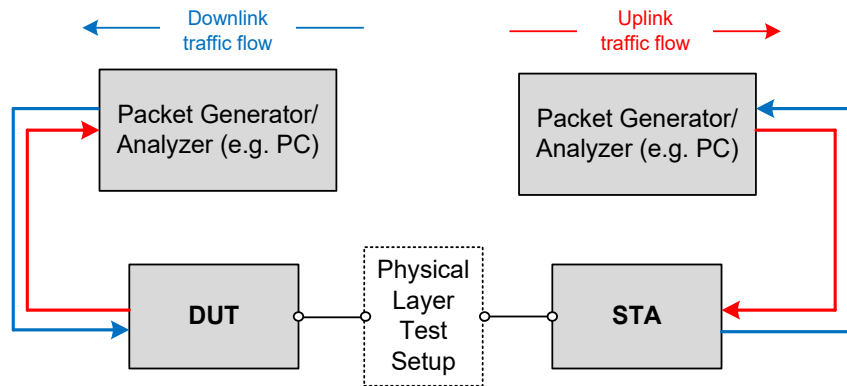


Figure 18: Test setup by using TCP/UDP flows with separate Packet Generator/Analyzer

Figure 18 shows typical examples when TCP/UDP flows are used in the test. Two independent Packet Generators/Analyzers are utilized for packet generation/analysis. In this case, STA/STAs SHALL provide interface to receive/forward packets from/to packet generation/analysis in STA side.

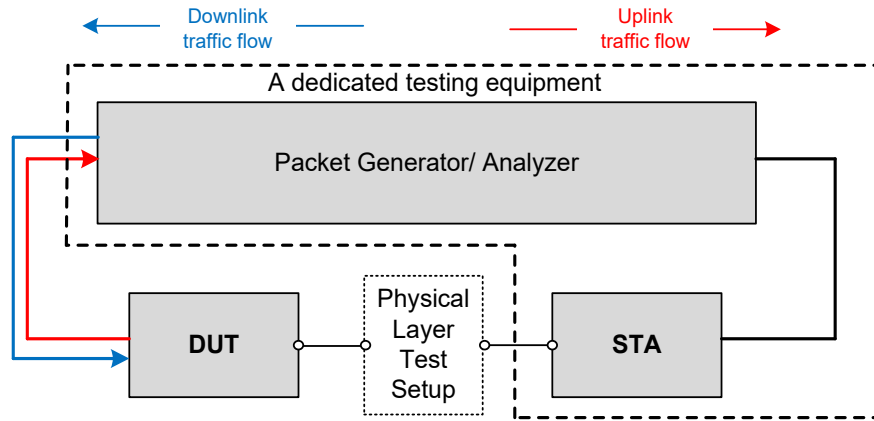


Figure 19: Test setup by using TCP/UDP flows with the dedicated testing equipment

Figure 19 shows another example for usage of TCP/UDP flows. The dedicated testing equipment containing a common Packet Generator/Analyzer and STA/STAs capability is used in the test.

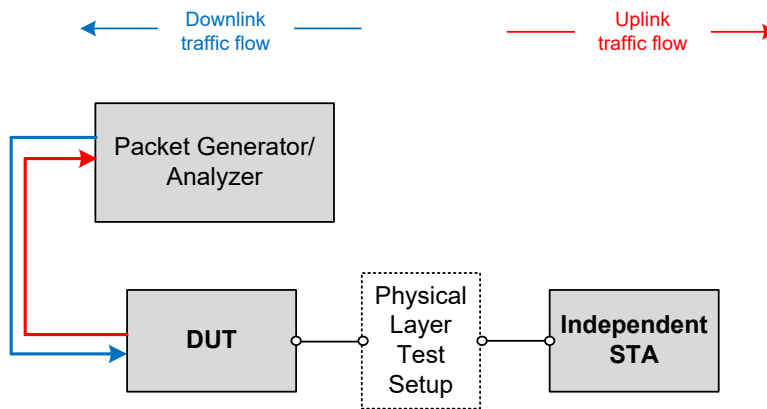


Figure 20: Test setup by using TCP/UDP flows with an independent STA

Figure 20 shows another example for usage of TCP/UDP flows. Independent STA/STAs (i.e., being capable to generate/analyze IP traffic) are used in the test. Additional software SHOULD be necessary to facilitate packet generation/reception within the STA/STAs. The software is out of scope in this test plan.

I.2 Test Setup by Using Level-2 Ethernet Packet

If level-2 Ethernet packet is required in the test, the Packet Generator/Analyzer for DUT side and the Packet Generator/Analyzer for STA side MAY be located in the same box.

Figure 21 shows a typical example when level-2 Ethernet flows are used in the test. A common Packet Generator/Analyzer provide bidirectional packet generation/reception. In this case, STA/STAs SHALL provide interface to receive/forward packets from/to packet generation/analysis in STA side.

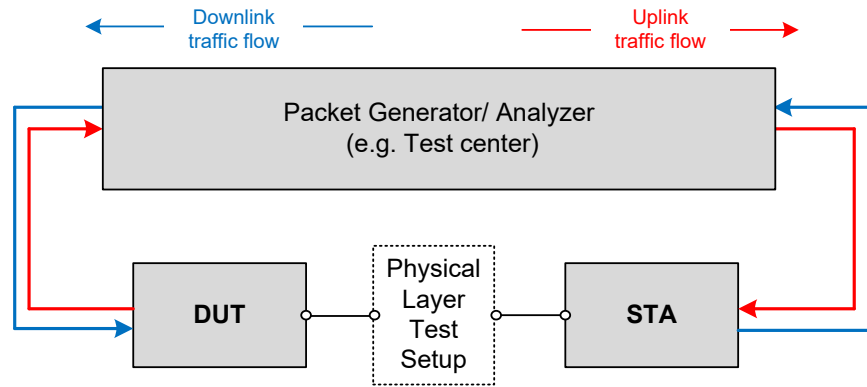


Figure 21: Test Setup by using level-2 Ethernet flows with a common Packet Generator/Analyzer

Appendix II. A Way to Verify STA RSSI

TR398 issue-3 introduces a well-defined calibration procedure. A calibration AP of known transmit power transmits to a STA and STA records the RSSI to determine path-loss. This depends on the STA reporting the correct RSSI, and some STA radios report RSSI significantly different than expected values.

To verify STA RSSI, one may use a known path-loss in a fully cabled environment. AP is cabled to Attenuator with known insertion loss, and Attenuator is set to additional path-loss to ensure the total path-loss is 60. Assuming a +20 transmitting AP, expected RSSI would be -40 in this example. Compare actual STA RSSI to the expected value to find the offset. This offset may be used to adjust the RSSI recorded during the calibration step to make the calibration more accurate.

Appendix III. Test Cases For Further Study

7.1.4 Multiple STAs Multicast Performance Test

7.1.4.1 Introduction

Multicast feature test intends to ensure that multicast works in the download direction with multiple STAs at different distances simultaneously. There are three sets of 3 stations, with each group at a different emulated distance. The different distances are to make sure the AP uses a reliable multicast encoding rate since there is no rate-control for multicast frames.

This test SHALL be OPTIONAL for the test plan

7.1.4.2 Setup

The same test setup shown in Figure 12 SHALL be used. Note the STA in Figure 12 is duplicated by 9 times in this test.

1. Total 9 STAs are engaged in the test. Three STAs are located in a close distance to the DUT. Three STAs are located in a medium distance to the DUT. The rest of the STAs are located in a fardistance to the DUT. The close/medium/far distance are emulated by adding additional attenuation for the signals as follows:
 - a) STA in close distance as defined in Table 8
 - b) STA in medium distance as defined in Table 8;
 - c) STA in far distances as defined in Table 8.
2. A Traffic Generator/Analyzer, sending the corresponding Ethernet packets to each STA, connects to the LAN interface (e.g., GE port) of the DUT.
3. Multicast streams SHALL be used in the test.
4. STAs shall be configured to use 2 spatial steams.

7.1.4.3 DUT Configuration

The test SHALL run under the following configuration:

1. General configuration for DUT/STA working mode, bandwidth and number of RF chains:

Table 52: DUT configuration for Multiple Association / Disassociation Stability Test

Wi-Fi configuration (DUT)	Wi-Fi configuration (Peer STA)	Bandwidth (MHz)
802.11n (NSS=2)	802.11n (NSS=2)	20
802.11ac (NSS=2)	802.11ac (NSS=2)	80
802.11ax (2.4 GHz, NSS=2)	802.11ax (2.4 GHz, NSS=2)	20
802.11ax (5 GHz, NSS=2)	802.11ax (5 GHz, NSS=2)	80

2. The general configuration SHALL be tested if the configuration is applicable for DUT.

7.1.4.4 Procedures

1. Configure the system to emulate a 2-meter distance. This is the baseline '0' attenuation.
2. Establish the LAN connection.
3. Create 3 sets of 3 stations using 2.4GHz N. Multicast transmitter speed is 500Kbps.
4. Group 1 is set to close distance, Group 2 is set to medium distance, and Group 3 is set to fardistance.
5. Create one UDP IPv4 multicast transmitter on the Ethernet port, configured to send at requested speed for the band and mode.
6. Create one UDP IPv4 multicast receiver on each station. The multicast receiver must use the same multicast IP and port as the transmitter so that it can receive traffic from the transmitter.
7. Start multicast transmitter and receivers. Wait for 30 seconds to allow IGMP to propagate.
8. Allow multicast endpoints to run for another 120 seconds, record each receiver's throughput over the last 120 seconds.
9. Stop multicast endpoints and disassociate stations.
10. Create or reconfigured the 3 sets of 3 stations to use 5GHz AC mode and/or configure the AP for 5GHz AC mode. Multicast transmitter speed is 3Mbps. Repeat steps 4 - 9 inclusive.
11. Create or reconfigured the 3 sets of 3 stations to use 2.4GHz AX mode and/or configure the AP for 2.4GHz AX mode. Multicast transmitter speed is 500Kbps. Repeat steps 4 - 9 inclusive.
12. Create or reconfigured the 3 sets of 3 stations to use 5GHz AX mode and/or configure the AP for 5GHz AX mode. Multicast transmitter speed is 3Mbps. Repeat steps 4 - 9 inclusive.

7.1.4.5 Metrics (Pass/Fail Criteria)

For each configuration, each multicast receiver endpoint must receive at least 99% of the transmitted data rate over the two-minute run time.

Pass/Fail requirements for Repeated Wi-Fi Throughput Performance Test Config 1

Config 1: 802.11n, NSS = 2, BW = 20 MHz				
(5 out of 6 requirements MUST pass)				
Attn B Value (dB)	Dual-band Wi-Fi Repeater		Tri-band Wi-Fi Repeater	
	Downlink Throughput Requirement (Mbps)	Uplink Throughput Requirement (Mbps)	Downlink Throughput Requirement (Mbps)	Uplink Throughput Requirement (Mbps)
30				
40				
50				

Pass/Fail requirements for Repeated Wi-Fi Throughput Performance Test Config 2

Config 2: 802.11ac, NSS = 2, BW = 80 MHz				
(5 out of 6 requirements MUST pass)				
Attn B Value (dB)	Dual-band Wi-Fi Repeater		Tri-band Wi-Fi Repeater	
	Downlink Throughput Requirement (Mbps)	Uplink Throughput Requirement (Mbps)	Downlink Throughput Requirement (Mbps)	Uplink Throughput Requirement (Mbps)
30				

40			
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Pass/Fail requirements for Repeated Wi-Fi Throughput Performance Test Config 3

Config 3: 802.11ax 2.4 GHz, NSS = 2, BW = 20 MHz				
(5 out of 6 requirements MUST pass)				
Attn B Value (dB)	Dual-band Wi-Fi Repeater		Tri-band Wi-Fi Repeater	
	Downlink Throughput Requirement (Mbps)	Uplink Throughput Requirement (Mbps)	Downlink Throughput Requirement (Mbps)	Uplink Throughput Requirement (Mbps)
30				
40				
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Pass/Fail requirements for Repeated Wi-Fi Throughput Performance Test Config 4

Config 4: 802.11ax 5 GHz, NSS = 2, BW = 80 MHz				
(5 out of 6 requirements MUST pass)				
Attn B Value (dB)	Dual-band Wi-Fi Repeater		Tri-band Wi-Fi Repeater	
	Downlink Throughput Requirement (Mbps)	Uplink Throughput Requirement (Mbps)	Downlink Throughput Requirement (Mbps)	Uplink Throughput Requirement (Mbps)
30				
40				
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End of Broadband Forum Technical Report TR-398