WORKING TEXT

DRAFT

WIFIPERF-53

WT-398i2

Wi-Fi Residential & SOHO Performance Testing

Rev: 15
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Rev History

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15	January 11, 2020	Lincoln Lavoie	• Output of the January 11, 2020 teleconference.
14	January 8, 2020	Lincoln Lavoie, UNH-IOL	• Implemented proposed pass/fail metrics for 2020-Q4 meeting.
13	November 25, 2020	Lincoln Lavoie, UNH-IOL	• Final straw ballot comment resolutions from October 26 teleconference.
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11	July 27, 2020	Lincoln Lavoie	• Editorial updates and clean up. • Added WIFIPERF-81
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07	May 11, 2020	Lincoln Lavoie, UNH-IOL	• Updated based on the May 11, 2020 teleconference
06	March 24, 2020	Lincoln Lavoie, UNH-IOL	• Updated based on the March 23, 2020 teleconference • Changes 802.11ax 2.4 GHz to 20 MHz channel bandwidths • Implemented changes from WIFIPERF-73. • Updated editors notes based on discussions.
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01	August 20, 2019	Lincoln Lavoie, UNH-IOL	• Updated based on agreements from July 29 teleconference.
00	July 29,2019	Lincoln Lavoie, UNH-IOL	• Baseline text from TR-398 Issue 1. • Changes from TR-398i1c1 applied to Table 15

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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 802.11ac [1].

The primary goal of WT-398i2 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 references Station (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 a or a set of STA.

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.

1 Purpose and Scope

1.1 Purpose

WT-398i2 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", and "Wi-Fi 6" for 802.11n, 802.11ac, and 802.11ax in Wi-Fi Alliance, respectively.

The primary goal of WT-398i2 Rev 15 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". WT-398i2 Rev 15 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. WT-398i2 Rev 15 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

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

2 References and Terminology

2.1 Conventions

In this Working Text, several words are used to signify the requirements of the specification. These words are always capitalized. More information can be found be 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 Working Text. At the time of publication, the editions indicated were valid. All references are subject to revision; users of this Working Text 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	*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)*	IETF	2016

	and Physical Layer (PHY) Specifications specification		
[2] RFC 2119	*Key words for use in RFCs to Indicate Requirement Levels*	IEEE	1997
[3] P.2040-1	*Effects of building materials and structures on radiowave propagation above about 100 MHz*	ITU-R	2015
[4] Report	*Building Materials and Propagation*	Ofcom	2014

EDITOR'S NOTE: 802.11ax is still a draft (until November), how to reference this update, or should we just reference 802.11 in general, if so, what date to use?

2.3 Definitions

The following terminology is used throughout this Working Text.

CPE	Customer Premises Equipment. In the context of this Working Text, 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.

2.4 Abbreviations

This Working Text uses the following abbreviations:

AP	Access Point
DL	Downlink
DTIM	Delivery Traffic Indication Message
DUT	Device Under Test
GE	Gigabit Ethernet
GUI	Graphical User Interface
ICMP	Internet Control Message Protocol
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
PC	Personal Computer
PER	Packet Error Rate
PHY	Physical Layer
QoS	Quality of Service
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 Working Text 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.

If the test case requires test traffic larger than 1 Gbps at the LAN interface, multiple Gigabit Ethernet ports SHALL be employed to fulfill the test traffic demand in the test. In this case, identical traffic streams with same Quality of Service (QoS) setting SHALL be injected to Gigabit Ethernet ports, respectively.

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.

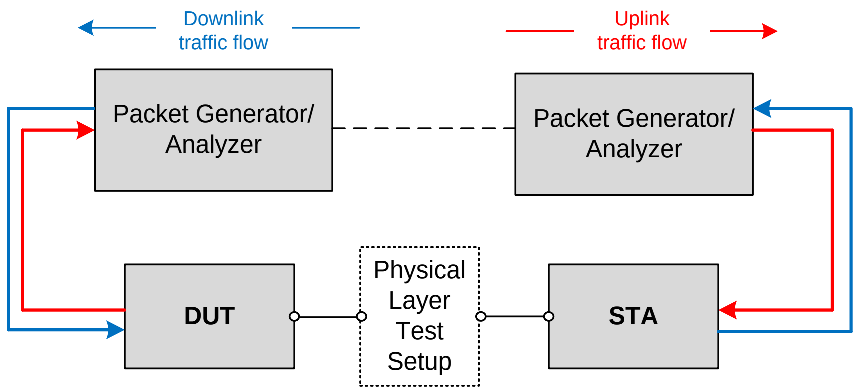

Figure 1: Test setup for performance testing for single STA

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 based on IPv4.
c) Create 10 and 1 measurement streams between DUT and each STA for TCP and UDP, respectively. The throughput between the DUT and STA is the summation of all the measurement streams.

d) No rate limitation SHALL be set for the TCP/UDP flow.
e) The data sent over the TCP SHALL be a randomized byte stream.

- Setting for TCP:

a) TCP window size SHALL be set as 64KB.
b) A code file (file size of 100000 bytes for 2.4GHz testing and 10000000 bytes for 5 GHZ testing) transaction SHALL be simulated in the TCP connection. This transaction SHALL be continuously conducted during the measurement time. The code file shall be a constructed of randomized bytes.
c) Each fragment of the file is sent continuously to operating system running the test software. The
d) TCP payload size SHOULD be determined by the operating system.

- Setting for UDP:

a) A code file (file size of 730000) transaction SHALL be simulated in the UDP connection. This transaction SHALL be continuously conducted during the measurement time. The code file shall be a constructed of randomized bytes.
b) The UDP payload size SHALL be set as 1460 bytes.

Note: This leads to 1472 bytes Ethernet frame size. The size of the transmitted data is 1460 bytes with 20-bytes IPv4 header and 8-byte UDP header.

5.1.3 Example: Ethernet traffic generation by iPerf3

Where the open source program iPerf3 is used to implement the traffic throughout 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 ten 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 Throughtput Measurement

iPerf3 --client <SERVER_IP> --time <TEST_TIME> --bitrate 0 –parallel 10 –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 need.

5.2 Test Setup Characteristics

Test results obtained as a result of testing performed in accordance with WT-398i2 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, the antenna SHALL be adjusted perpendicularly to the horizontal plane.

c. If path-loss is used, then the peer STA SHALL be separated from the DUT by the equivalent free space path loss at the working frequency. Free space path loss between isotropic antennas is expressed as $P\_L\ (dB)=20\ Log_{10}\ (f\_GHz\ ) + 20\ Log_{10}\ (d\_meters\ ) + 32.45$. For example, at 2.4 GHz the path loss equivalent to a 1-meter separation is 40 dB, and at 5.2 GHz the path loss is 46.8 dB. The attenuation value for testing SHALL be rounded to the nearest whole dB value.

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. Note that one difficulty in this implementation is in gaining access to the STA antenna ports, which will not be possible with all STAs.

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 spacing requirements defined in each test case.

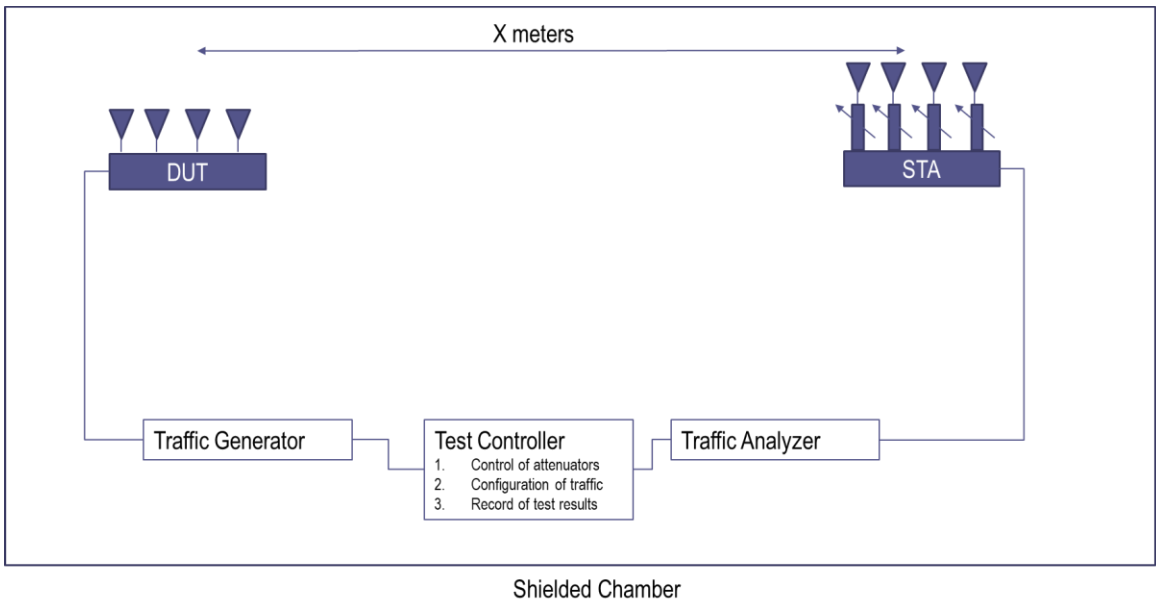

Figure 2: Single Chamber Implementation

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. Note that in this implementation the variable attenuation is available without access to the DUT or STA antenna ports. 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. The distance (Distance$_{DUT_Probe}$) between the probe antennas and the DUT/STA SHALL be less than 0.5 meter.

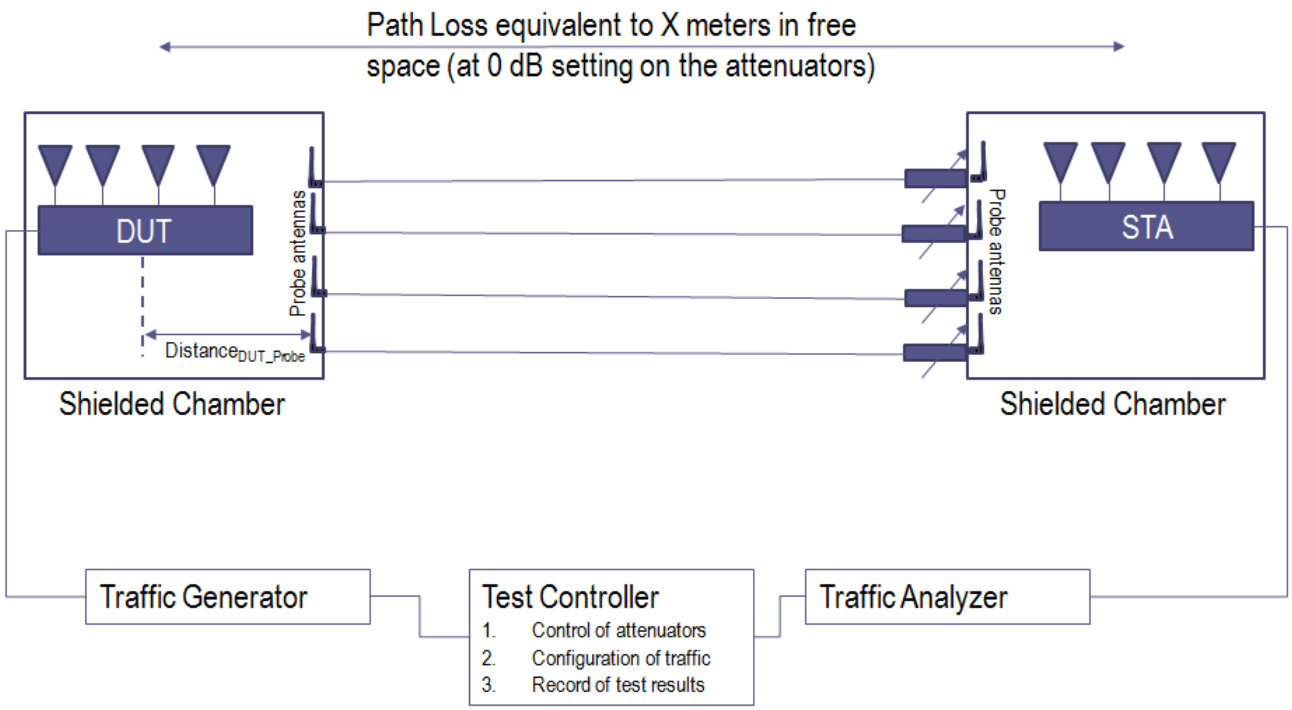

Figure 3: Multiple Chamber Implementation

5.2.2.3 Wi-Fi Mesh Multiple Chamber Implementation

This test environment is used to create a controlled RF path between 3 separate isolation chambers, as an expansion of the Multiple Chamber Implementation described above. In this test environment, the 3 isolation chambers are separated using 3 sets of attenuators (labeled as Attn A, Attn B, and Attn C). 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 repeater 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.

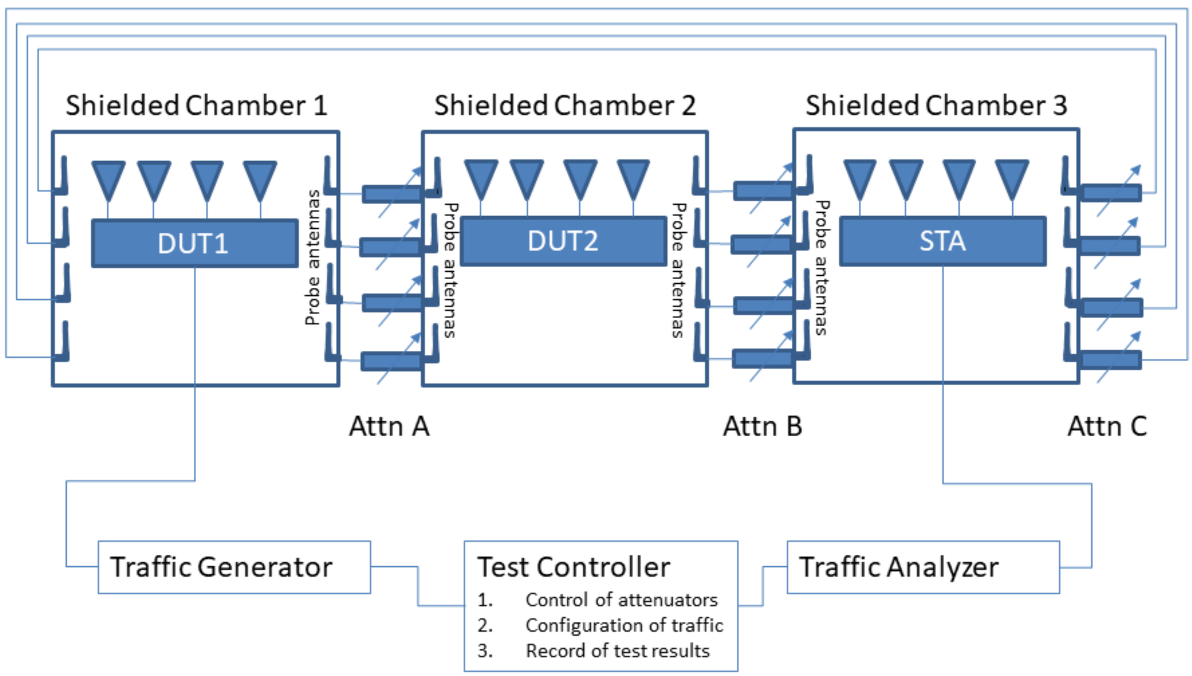

Figure 4: Wi-Fi Mesh Multiple Chamber Implementation

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 have at least the same Wi-Fi physical layer capability (i.e., maximum spatial streams supported and antenna number) as the DUT unless the test case specifies the capability of the STA used in the test. The STA(s) MAY support physical layer capabilities exceeding those of the DUT.

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 required 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.

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.

If the DUT supports multiple Wi-Fi channels, the DUT SHALL select channel 6 for 2.4 GHz frequency band and channel 36 for 5 GHz frequency band. 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.

5.3.2 SSID setting

The setting for Service Set Identifier (SSID) SHALL be configured as defined in Table 8. SSID for 2.4GHz and 5GHz band SHALL be set up separately. The DUT SHALL be configured to enable only one SSID 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 8: 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	WPA2-Personal

Encryption Mode	AES
WPA PreShareKey	(NOTE2)
WPA Group Key Regeneration Interval	3600 seconds
Note 1: "X" represent "2.4" when DUT is configured to work in 2.4 GHz band while "X" represent "5" when DUT is configured to work in 5 GHz band. **Note 2:** Defined by test agent.	

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, where the distance and test channels are defined as absolute attenuation values. In this context, the transmit power is the power delivered to the antenna by the transmit power amplifier within the DUT.

The DUT SHALL be configured to use the transmit power identified within this section, along with the indicated Wi-Fi channel. If the DUT cannot change the used transmit power for the indicated channel, the following changes SHALL be applied to the testing.

- The testing SHALL be conducted using an alternate channel in the same band that supports the required transmit power and channel width, as specified within the Tables 9, 10, and 11 below. Note, any change to the Wi-Fi channel used for testing of the DUT will require corresponding changes to channels used in the AP Coexistence Test Case.
- If an alternate channel or change to the transmit power level cannot be used for testing, the attenuation values or separation distance used for each test case SHALL be changed by the corresponding difference in power. For example, if the DUT only supports a maximum transmit power of 16 dBm for 2.4 GHz (as opposed to the 20 dBm as specified in Table 9), the attenuations or base distances used for each test case would be reduced by 4 dB. Or, if the DUT is only able to transmit at a power of 26 dBm for 2.4 GHz (as opposed to the 20 dBm as specified in Table 9), the attenuations or base distances used for each test case would be increased by 6 dB.
  - Changes in the attenuation values or distances SHALL NOT be made to account for DUT antenna design or performance. For example, the attenuation values would not be changed for a DUT designed to conform to the 20 dBm power allowed in the USA regulatory domain, where the STA is observed to report a lower than expected RSSI value, as this difference is likely directly related to the DUT antenna performance.
- All changes to the channel or attenuator values used in the testing SHALL be documented in the report.

Note, the above changes are intended to account for differences within the design and construction of the DUT, as required by its intended regulatory domain, while not “tuning” the test environment to each individual DUT, including its antenna and radiation pattern performance, which would obscure differences between the “real world” performance of individual DUTs.

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 9.

Table 9: Work setting configuration for 802.11n 2.4 GHz band

Configuration Parameters	Default value
Tx Power	100 % (NOTE 1)
Regulatory Domain	(NOTE 2)
Channel	Channel 6
Chanel Width	20 MHz
Standard mode	802.11n (NOTE 3)
Note 1:100% is corresponding to 20 dBm, this value indicates the aggregated power of all the chains used for communication by air-interface. **Note 2:** Defined by test agent or automatically selected by the DUT. **Note 3:** 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. The test plan for 802.11n working in 5 GHz is left for further study.

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 10.

Table 10: Work setting configuration for 802.11ac 5 GHz band

Configuration Parameters	Default value
Tx Power	100 % (NOTE 1)
Regulatory Domain	(NOTE 2)
Channel	Channel 36
Chanel Width	20/40/80 MHz
Standard mode	802.11ac (NOTE 3)

Note 1:100% is corresponding to 23 dBm, this value indicates the aggregated power for all the chains used for communication by air-interface.

Note 2: defined by test agent or automatically selected by the DUT.

Note 3: 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. Both bands SHALL be tested. The default setting for work mode SHALL be configured as defined in Table 11.

Table 11: Work setting configuration for 802.11ax (2.4 & 5 GHz band)

Configuration Parameters	Default value
Tx Power	100 % (NOTE1)
Regulatory Domain	(NOTE2)
Channel (NOTE 3)	Channel 6 or 36
Chanel Width	20 MHz for 2.4 GHz 20/40/80 MHz for 5 GHz
Standard mode	802.11ax

Note 1:100% is corresponding to 20 dBm or 23 dBm for 2.4 GHz and 5 GHz respectively, this value indicates the aggregated power for all the chains used for communication by air-interface.

Note 2: Defined by test agent or automatically selected by the DUT.

Note 3: Channel 6 SHALL be used for 2.4 GHz testing, Channel 36 SHALL be used for 5 GHz testing.

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 coding scheme, 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 coding schemes, ensuring the DUT should smoothly transition between coding schedules 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 5) 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.
4. The STA SHALL use omnidirectional antenna for packet transmission.
5. A rotation platform is used to rotate the DUT for angle-based data collection.

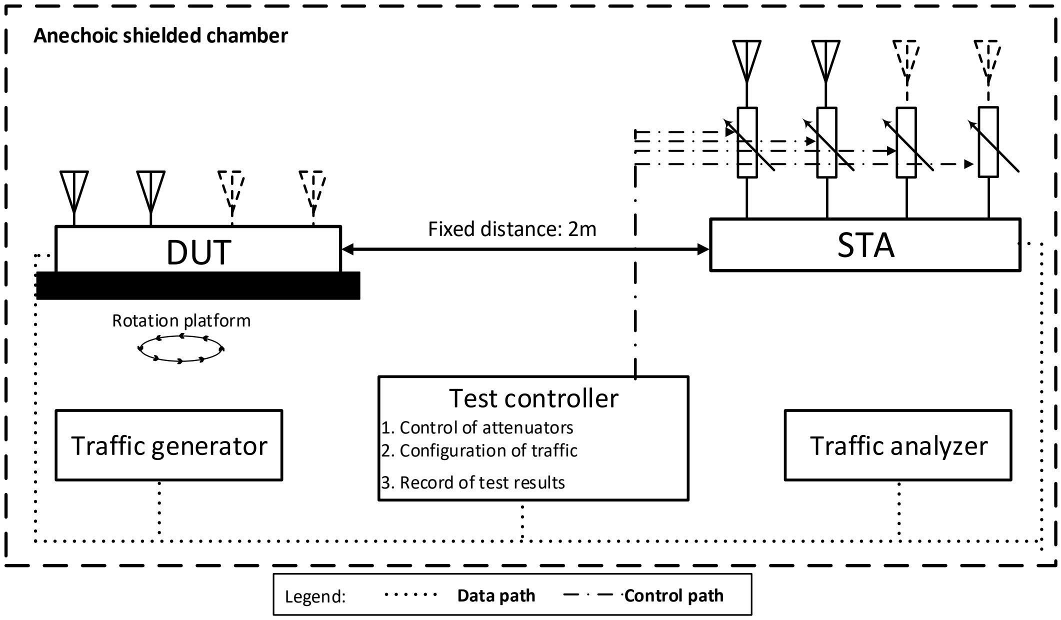

Figure 5: Test Setup for Receiver Sensitivity

6.1.1.3 DUT Configuration

The test SHALL be run using the each of the configurations from Table 12 below supported by the DUT. The test SHALL be conducted to the configurations that the DUT supports.

Table 12: 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 13, Table 14, Table 15, or Table 16 applicable to the test configuration from Table 12.
3. Configure the Traffic Generator to use the test data rate from Table 13, Table 14, Table 15, or Table 16 for the configured MCS rate.
4. Allow STA to associate with the DUT.
5. Configure the attenuator(s) to 0 dB.
6. Enable packet generation from the STA to the DUT for 20 seconds.

7. Record packet error rate (PER).
8. Increase the attenuator by 1 dB and repeat steps 6-8 until the PER is greater than 10%. Record the final attenuation value as the approximate receiver sensitivity.
9. 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.
10. Repeat steps 1 through 9 for each test index from Table 13, Table 14, Table 15, or Table 16 applicable to each test configuration from Table 12.
11. Repeat steps 1 through 10 for each test configuration in Table 12 supported by the DUT.

Table 13: 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 14: 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 15: 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
4	0	BPSK	8	5.2
5	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 16: 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 17 and Table 18.

Table 17: Required Receiver Sensitivity for 802.11n

Test Index	MCS Index	Modulation	Approximately Receiver Sensitivity (dB)
			Required (Nss=1)
1	0	BPSK	56
2	7	64-QAM	38

Table 18: Required Receiver Sensitivity for 802.11ac

Test Index	MCS Index	Modulation	Approximately Receiver Sensitivity (dB)
			Required (Nss=1)
3	0	BPSK	46
4	9	256-QAM	21

Table 19: Required Receiver Sensitivity for 802.11ax 2.4 GHz

Test Index	MCS Index	Modulation	Approximately Receiver Sensitivity (dB)
			Required (Nss=1)
1	0	BPSK	56
2	11	1024-QAM	33

Table 20: Required Receiver Sensitivity for 802.11ax 5 GHz

Test Index	MCS Index	Modulation	Approximately Receiver Sensitivity (dB)
			Required (Nss=1)
1	0	BPSK	46
2	11	1024-QAM	21

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 6) 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 is put at a distance of 2 meters to the DUT (For 2.4 GHz band, 2 meters free space of wireless channel leads to 46 dB attenuation).
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.

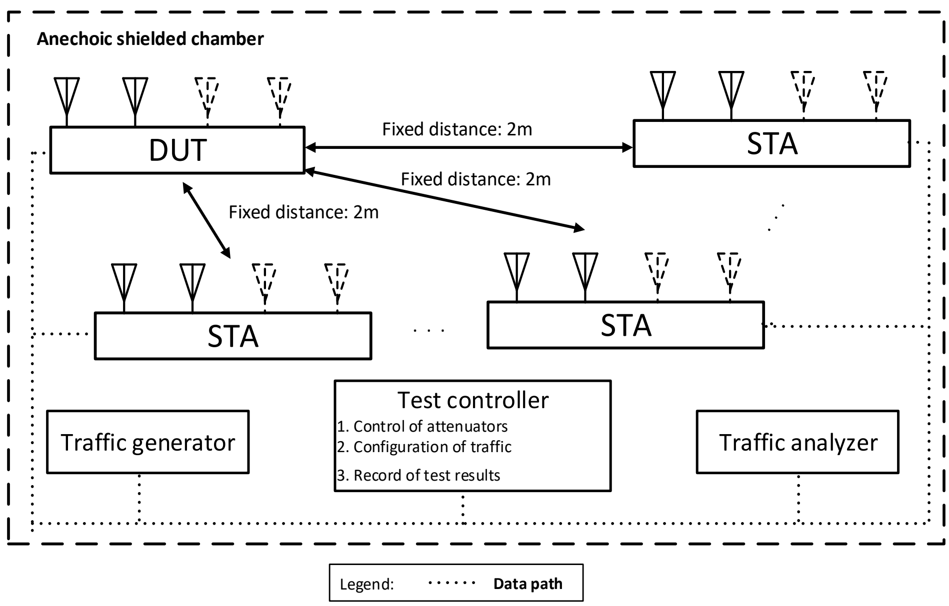

Figure 6: Test setup of Maximum Connection Test

> **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 works in different modes if applicable:

a) 802.11n
b) 802.11ac
c) 802.11ax over 2.4 GHz
d) 802.11ax over 5 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, or 10 Mbps for 802.11ax over 5 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, or 10 Mbps for 802.11ax over 5 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 configuration, 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 2.4 GHz), 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 7) 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. The peer STA is put at a distance of 2 meters to the DUT (For 2.4 GHz band, 2 meter free space of wireless channel leads to 46 dB attenuation).
3. TCP connection SHALL be used for Ethernet packet transmission in the test.

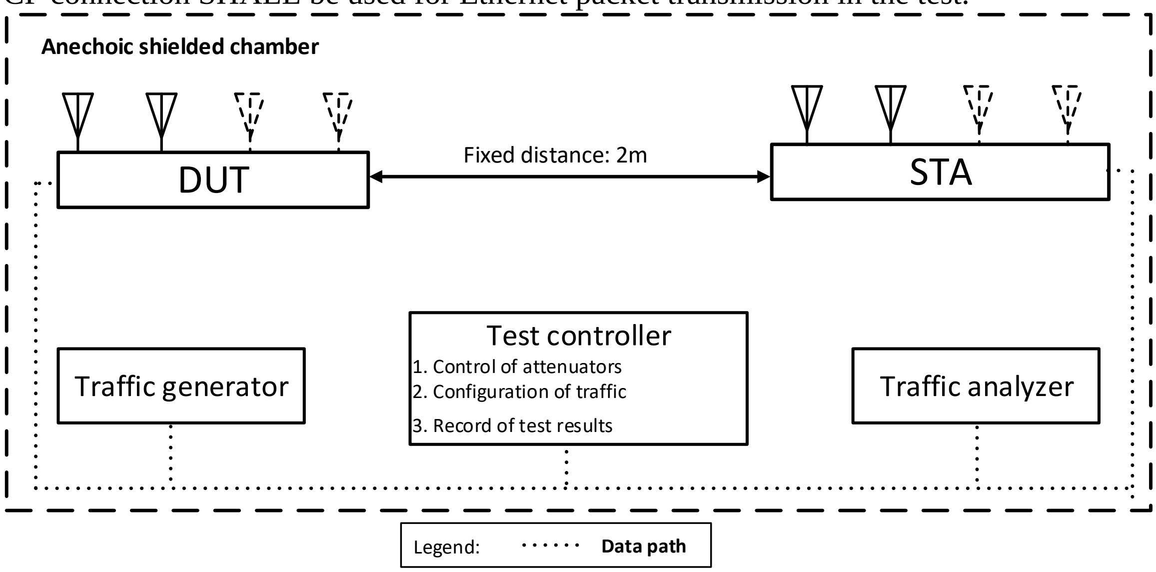

Figure 7: Test setup of Maximum Throughput Test

6.2.2.3 DUT configuration

The test SHALL run under the following configuration:

1. The DUT works in different modes:
   a) 802.11n
   b) 802.11ac
   c) 802.11ax over 2.4 GHz
   d) 802.11ax over 5 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 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 for bandwidth 80MHz.

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.

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 21 according to the GI used in the test.

Table 21: The Throughput Requirement

Wi-Fi configuration (DUT)	**Wi-Fi configuration (Peer STA)**	**Bandwidth (MHz)**	**Downlink throughput requirement （Mbps） GI=400ns**	**Uplink throughput requirement （Mbps） GI=400ns**	**Downlink throughput requirement （Mbps） GI=800ns**	**Uplink throughput requirement （Mbps） GI=800ns**
802.11n (Nss=2)	802.11n (Nss=2)	20	100	100	90	90
802.11ac (Nss=2)	802.11ac (Nss=2)	80	560	560	504	504
802.11ax (2.4 GHz, NSS=2)	802.11ax (2.4 GHz, NSS=2)	20	N/A	N/A	200	200
802.11ax (5 GHz, NSS=2)	802.11ax (5 GHz, NSS=2)	80	N/A	N/A	720	720

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 air time 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 SHALL be MANDATORY for the test plan.

6.2.3.2 Setup

1. The test setup (shown in Figure 8) SHALL locate 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 devices with the same number of spatial streams supported by the DUT in both 2.4 and 5GHz bands. STA3 is a legacy 802.11a/b/g, 802.11n Nss = 1, or 802.11ac Nss = 1 devices, depending on the operating mode under test. All STAs are located in the distance of 2 meter to the DUT (For 2.4 GHz band, 2 meter free space of wireless channel leads to 46 dB attenuation).
3. 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.
5. The TCP connection SHALL be used for Ethernet packet transmission in the test.

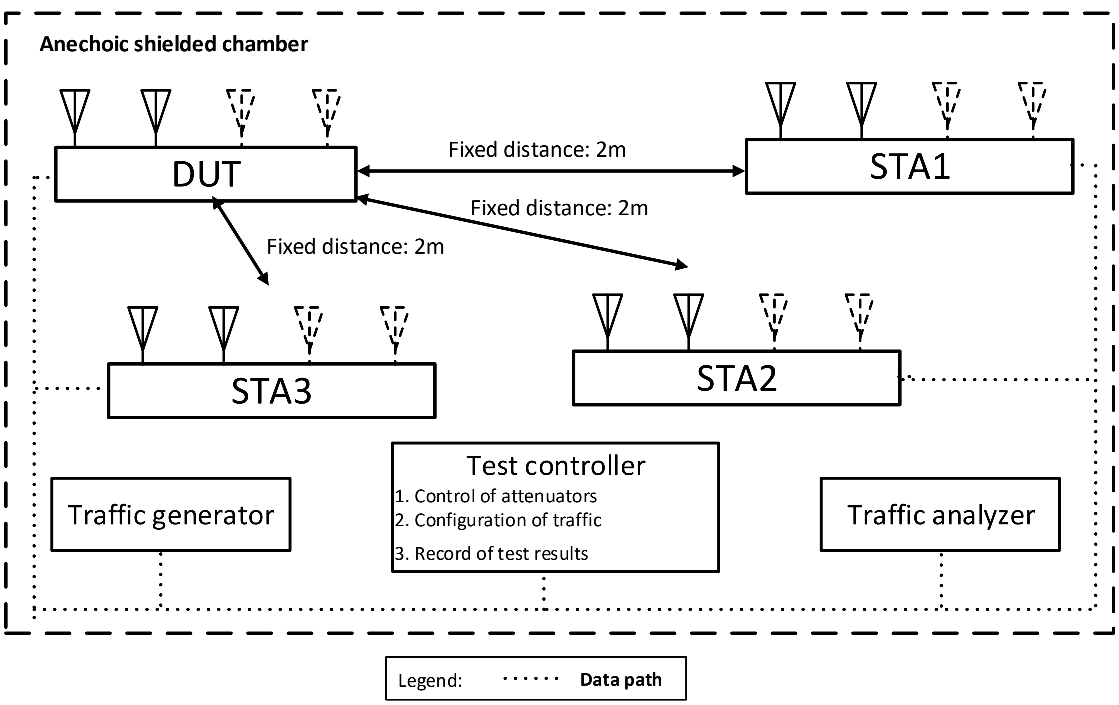

Figure 8: Test setup of Airtime Fairness Test

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 operating mode.
2. Associate STA1 and STA2 with DUT. Establish the LAN connection and wait for 10 seconds.
3. Measure the downlink TCP throughput to each STA1 and STA2, using a test time of 120 seconds. Record this as STA1 _throughput_1 and STA2 _throughput_1.
4. Move STA2 to a medium distance to the DUT (equivalent to 38 dB@2.4GHz and 25 dB @5GHz attenuation between DUT and STA2). Wait for 10 seconds.
5. Measure the downlink TCP throughput to STA 1 and STA2, using a test time of 120 seconds. Record this as STA1 _throughput_2 and STA2 _throughput_2.
6. Disassociate STA2 with the DUT. Replace STA 2 by STA 3 and remove the attenuation. STA3 is configured to support only a 2.4 GHz connection. Establish the Wi-Fi connection between STA3 and DUT and wait for 10 seconds.
7. Measure the downlink TCP throughput to STA 1 and STA3, using a test time of 120 seconds. Record this as STA1 _throughput_3 and STA3 _throughput_3.
8. Replace STA3 with a STA that uses only 802.11a. Set the DUT to operating mode of 802.11ac. Repeat steps 2 to 7.
9. Replace STA3 with a STA that uses only 802.11n. Set the DUT to operating mode of 802.11ax 2.4 GHz. Repeat steps 2 to 7.
10. Replace STA3 with a STA that uses only 802.11ac. Set the DUT to operating mode 802.11ax 5 GHz. Repeat steps 2 to 7.

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) The throughput variation of DUT SHALL meet:

For the test in 802.11n 2.4 GHz frequency band:

1) STA1_throughput_1 SHALL be within (1±5%)*Mean(STA2_throughput_1, STA1_throughput_1) .
2) STA2_throughput_1 SHALL be within (1±5%)*Mean(STA2_throughput_1, STA1_throughput_1) .
3) STA1_throughput_2 SHALL be within (1±15%)*Mean(STA2_throughput_1, STA1_throughput_1) .
4) STA1_throughput_3 SHALL be within (1±15%)*Mean(STA2_throughput_1, STA1_throughput_1).

For the test in 802.11ac 5 GHz frequency band:

1) STA1_throughput_1 SHALL be within (1±10%)*Mean(STA2_throughput_1, STA1_throughput_1).

2) STA2_throughput_1 SHALL be within (1±10%)*Mean(STA2_throughput_1, STA1_throughput_1).
3) STA1_throughput_2 SHALL be within (1±35%)*Mean(STA2_throughput_1, STA1_throughput_1).
4) STA1_throughput_3 SHALL be within (1±35%)*Mean(STA2_throughput_1, STA1_throughput_1).

For the test in 802.11ax 2.4 GHz frequency band:

1) STA1_throughput_1 SHALL be within (1±5%)*Mean(STA2_throughput_1, STA1_throughput_1) .
2) STA2_throughput_1 SHALL be within (1±5%)*Mean(STA2_throughput_1, STA1_throughput_1) .
3) STA1_throughput_2 SHALL be within (1±15%)*Mean(STA2_throughput_1, STA1_throughput_1) .
4) STA1_throughput_3 SHALL be within (1±15%)*Mean(STA2_throughput_1, STA1_throughput_1).

For the test in 802.11ax 5 GHz frequency band:

1) STA1_throughput_1 SHALL be within (1±20%)*Mean(STA2_throughput_1, STA1_throughput_1).
2) STA2_throughput_1 SHALL be within (1±20%)*Mean(STA2_throughput_1, STA1_throughput_1).
3) STA1_throughput_2 SHALL be within (1±35%)*Mean(STA2_throughput_1, STA1_throughput_1).
4) STA1_throughput_3 SHALL be within (1±35%)*Mean(STA2_throughput_1, STA1_throughput_1).

b) The throughput of DUT SHALL meet:

For the test in 802.11n 2.4 GHz frequency band with Nss = 2:

1) The summation of STA1_throughput_1 and STA2_throughput_1 SHALL be larger than 90 Mbps.
2) The summation of STA1_throughput_2 and STA2_throughput_2 SHALL be larger than 80 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 with Nss = 2:

1) The summation of STA1_throughput_1 and STA2_throughput_1 SHALL be larger than 570 Mbps.
2) The summation of STA1_throughput_2 and STA2_throughput_2 SHALL be larger than 570 Mbps.
3) The summation of STA1_throughput_3 and STA3_throughput_3 SHALL be larger than 265 Mbps.

For the test in 802.11ax 2.4 GHz frequency band with Nss = 2:

1) The summation of STA1_throughput_1 and STA2_throughput_1 SHALL be larger than 160 Mbps.
2) The summation of STA1_throughput_2 and STA2_throughput_2 SHALL be larger than 108 Mbps.
3) The summation of STA1_throughput_3 and STA3_throughput_3 SHALL be larger than 100 Mbps.

For the test in 802.11ax 5 GHz frequency band with Nss = 2:
1) The summation of STA1_throughput_1 and STA2_throughput_1 SHALL be larger than 610 Mbps.
2) The summation of STA1_throughput_2 and STA2_throughput_2 SHALL be larger than 360 Mbps.
3) The summation of STA1_throughput_3 and STA3_throughput_3 SHALL be larger than 295 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, 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. 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, but not both bands simultaneously. This test requires at least 2 stations, located 2m from the DUT. 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.

This test SHALL be MANDATORY for the test plan.

6.2.4.2 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), using 2 stations.
2. The peer STAs are put at a distance of 2 meters to the DUT. For 2.4 GHz band, 2 meters free space of wireless channel leads to 46 dB attenuation.
3. Additional attenuation is added in each RF chain of STA to simulate the incremental distance. Configure the attenuators to an initial value of 10 dB.
4. Configure one station to enable only the 2.4 GHz band, configure the other station to enable only the 5 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.

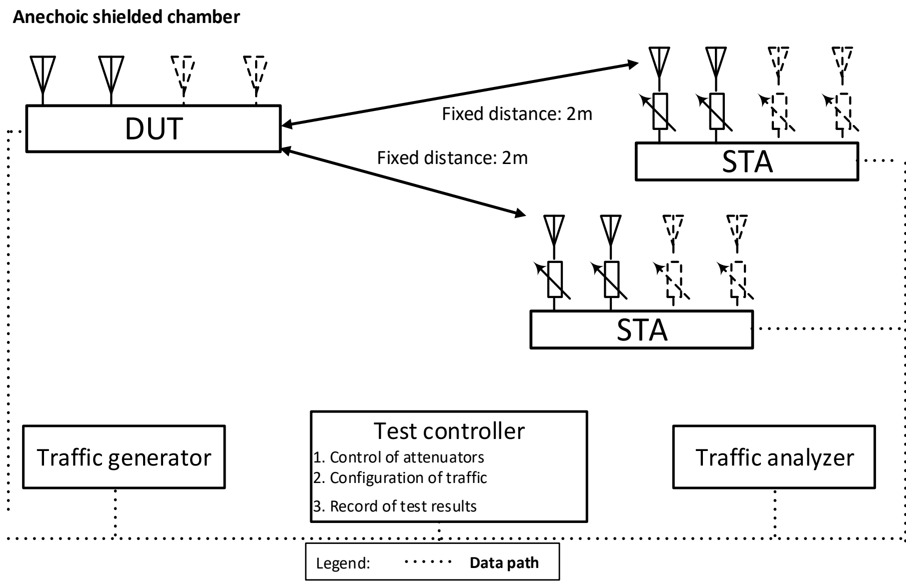

Figure 9: Test setup Dual-band Throughput Test

6.2.4.3 DUT configuration

The test SHALL run under the following configuration:

1. The DUT works in different modes:
    a. 802.11n and 802.11ac
    b. 802.11ax 2.4 GHz and 802.11ax 5 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.
4. Simultaneously measure the uplink TCP throughput to all STA, using a test time of 120 seconds
5. Simultaneously measure the downlink TCP throughput to the 802.11n STA and the uplink TCP throughput to the 802.11ac STA.
6. Simultaneously measure the uplink TCP throughput to the 802.11n STA and the downlink TCP throughput to the 802.11ac STA.
7. Repeat steps 1 through 6 with the attenuators set to 32 dB for 2.4 GHz STA and 25 dB for 5 GHz STA.
8. Repeat steps 1 through 6 with the attenuators set to 42 dB for 2.4 GHz STA and 35 dB for 5 GHz STA.
9. Repeat steps 1 through 8 for each configuration listed above in 6.2.4.3.

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.
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 performance requirements of Table 22.

Table 22: Dual-band Throughput Test Requirements

Test Point	Additional Attenuation (dB)	Description	Throughput Requirements			
			2.4 GHz		5 GHz	
			Downlink (Mbps)	Uplink (Mbps)	Downlink (Mbps)	Uplink (Mbps)
1	10	Simultaneous downlink on 802.11n and 802.11ac	100	N/A	500	N/A
2	10	Simultaneous uplink on 802.11n and 802.11ac	N/A	100	N/A	500
3	10	Downlink through 802.11n, uplink through 802.11ac	100	N/A	N/A	500
4	10	Uplink through 802.11n, downlink through 802.11ac	N/A	100	500	N/A
5	25/32	Simultaneous downlink on 802.11n and 802.11ac	85	N/A	380	N/A
6	25/32	Simultaneous uplink on 802.11n and 802.11ac	N/A	85	N/A	380
7	25/32	Downlink through 802.11n, uplink through 802.11ac	85	N/A	N/A	380
8	25/32	Uplink through 802.11n, downlink through 802.11ac	N/A	85	380	N/A
9	35/42	Simultaneous downlink on 802.11n and 802.11ac	45	N/A	175	N/A
10	35/42	Simultaneous uplink on 802.11n and 802.11ac	N/A	45	N/A	175
11	35/42	Downlink through 802.11n, uplink through 802.11ac	45	N/A	N/A	175
12	35/42	Uplink through 802.11n, downlink through 802.11ac	N/A	45	175	N/A
13	10	Simultaneous downlink on 802.11ax 2.4 GHz and 802.11ax 5 GHz	195	N/A	700	N/A
14	10	Simultaneous uplink on 802.11ax 2.4 GHz and 802.11ax 5 GHz	N/A	195	N/A	700

15	10	Downlink through 802.11ax 2.4 GHz, uplink through 802.11ax 5 GHz	195	N/A	N/A	700
16	10	Uplink through 802.11ax 2.4 GHz, downlink through 802.11ax 5 GHz	N/A	195	700	N/A
17	25/32	Simultaneous downlink on 802.11ax 2.4 GHz and 802.11ax 5 GHz	130	N/A	400	N/A
18	25/32	Simultaneous uplink on 802.11ax 2.4 GHz and 802.11ax 5 GHz	N/A	130	N/A	400
19	25/32	Downlink through 802.11ax 2.4 GHz, uplink through 802.11ax 5 GHz	130	N/A	N/A	400
20	25/32	Uplink through 802.11ax 2.4 GHz, downlink through 802.11ax 5 GHz	N/A	130	400	N/A
21	35/42	Simultaneous downlink on 802.11ax 2.4 GHz and 802.11ax 5 GHz	75	N/A	250	N/A
22	35/42	Simultaneous uplink on 802.11ax 2.4 GHz and 802.11ax 5 GHz	N/A	75	N/A	250
23	35/42	Downlink through 802.11ax 2.4 GHz, uplink through 802.11ax 5 GHz	75	N/A	N/A	250
24	35/42	Uplink through 802.11ax 2.4 GHz, downlink through 802.11ax 5 GHz	N/A	75	250	N/A
Notes: 1. Note, the requirements per each row apply to measurements made simultaneously (at the same time) for the described test point. 2. If the DUT can only support the long guard interval (GI = 800 ns), the performance requirements above SHALL be reduced by 10%. 3. For 802.11ax, all performance requirements refer to guard interface of GI =800 ns.							

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 7) SHALL be located in the anechoic shielded chamber (see section 5.2.1 and 5.2.2). The peer STA is put at a distance of 2 meters to the DUT (For 2.4 GHz band, 2 meters free space of wireless channel leads to 46 dB attenuation).
2. Configure the DUT and STA to use the 2.4 GHz band, per the settings in Section 5.3.
3. Configure the attenuator to 10 dB.

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.

6.2.5.3 DUT configuration

The test SHALL run under the following configuration:

1) The DUT works in different modes:
   a) 802.11n
   b) 802.11ac
   c) 802.11ax over 2.4 GHz
   d) 802.11ax over 5 GHz

6.2.5.4 Procedures

1. Establish the LAN connection and allow the STA to associate with the DUT.
2. Measure the achievable downlink TCP throughput, using a test time of 120 seconds. Record this value as Throughput_Max_DL.
3. Measure the achievable uplink TCP throughput, using a test time of 120 seconds. Record this value as Throughput_Max_UL.
4. Configure bidirectional UDP traffic streams to use an dowplink 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.
5. Simultaneously run the bidirectional UDP traffic for 120 seconds, recording the number of packets transmitted, received, and dropped in each direction.
6. 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.
7. Repeat steps 1 through 6 for attenuator settings 21 dB and 42 dB for 2.4 GHz DUT configurations or 21 dB and 35 dB for 5 GHz DUT configurations.
8. Repeat steps 1 through 7 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.

6.3 Coverage

6.3.1 Range Versus Rate Test

6.3.1.1 Introduction

Range versus rate test intends to measure 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 10) SHALL locate 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. The peer STA is located 2 meters to the DUT (46dB attenuation for 2.4 GHz, 53 dB attenuation for 5.2 GHz).
3. Additional attenuation is added to simulate the incremental distance. The specific attenuation values used for testing are defined in 6.3.1.3.
4. The host SHALL send the Ethernet packet at the maximum rate which the DUT can achieve theoretically.
5. 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 ~ 63dB 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.

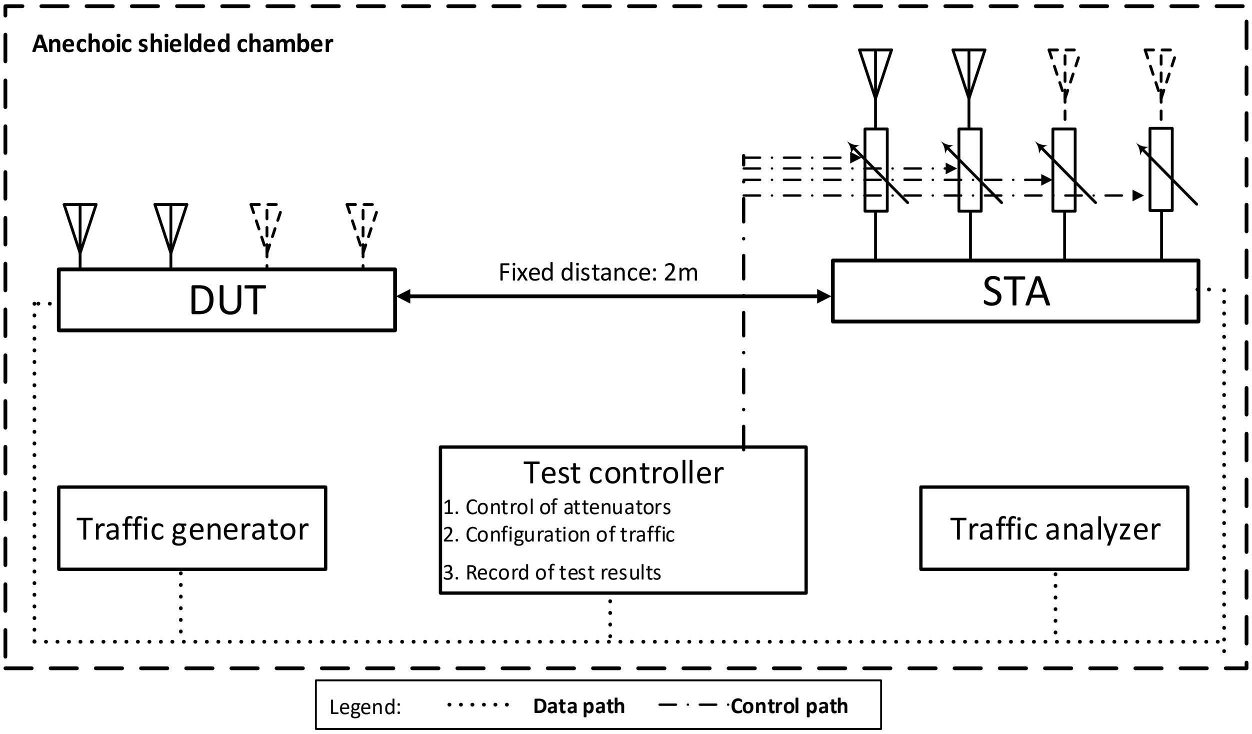

Figure 10: Test setup of Range Versus Rate Test

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 23: General configuration for range vs rate 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. Additional attenuation for STA RF chain during the test, see Table 24.

Table 24: 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), 10 dB, 21 dB, 24 dB, 27 dB, 30 dB, 33 dB, 36 dB, 39 dB, 42 dB, 45 dB, 48 dB, 51 dB, 54 dB, 57 dB, 60 dB, 63 dB
Additional attenuation for test of 802.11ac and 802.11ax 5 GHz	0 dB (default), 10 dB, 21 dB, 24 dB, 27 dB, 30 dB, 33 dB, 36 dB, 39 dB, 42 dB, 45 dB, 48 dB, 51 dB, 54 dB

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.
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. Change the attenuation for STA RF chain according to 6.3.1.3 until the attenuation reaches to 63 dB. Repeat step 2-4.
6. Configure the attenuator with 0 dB attenuation. Set the working mode of DUT to 802.11ac with 80MHz bandwidth. Repeat step 2-4 for all attenuation values in section 6.3.1.3.
7. Configure the attenuator with 0 dB attenuation. Set the working mode of DUT to 802.11ax over 2.4 GHz with 20MHz bandwidth. Repeat step 2-4 for all attenuation values in section 6.3.1.3.
8. Configure the attenuator with 0 dB attenuation. Set the working mode of DUT to 802.11ax over 5 GHz with 80MHz bandwidth. Repeat step 2-4 for all attenuation values in section 6.3.1.3.

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 25. 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 25: 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	
	Throughput Requirement (Mbps)		Throughput Requirement (Mbps)		Throughput Requirement (Mbps)		Throughput Requirement (Mbps)	
	DL	UL	DL	UL	DL	DL	DL	UL
0	100	100	560	560	200	200	720	720
10	100	100	530	530	200	200	680	680
21	100	100	420	420	200	200	540	540
24	100	100	400	400	200	200	515	515
27	100	100	360	360	200	200	465	465
30	100	100	300	300	180	180	400	400
33	100	100	220	220	170	170	350	300

36	95	95	150	150	150	150	300	225
39	80	80	125	125	120	120	200	175
42	75	75	100	100	90	90	175	150
45	50	50	45	45	85	85	150	50
48	45	31	25	25	65	65	50	25
51	35	24	5	5	55	50	7	5
54	25	17	1	1	30	25	2	2
57	14	12	N/A	N/A	25	20	N/A	N/A
60	9	7	N/A	N/A	15	10	N/A	N/A
63	8	4	N/A	N/A	10	5	N/A	N/A

6.3.2 Spatial consistency test

6.3.2.1 Introduction

Spatial consistency test intends to verify 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 11) SHALL locate in the anechoic shielded chamber (see section 5.2.1 and 5.2.2), DUT and peer STA is in a distance of 2 meters. DUT is fixed in a two-dimensional rotation platform.
2. 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.
3. Additional attenuation is added to simulate the incremental distance. The concrete values are defined in 6.3.2.3.
4. TCP connection SHALL be used for Ethernet packet transmission in the test.

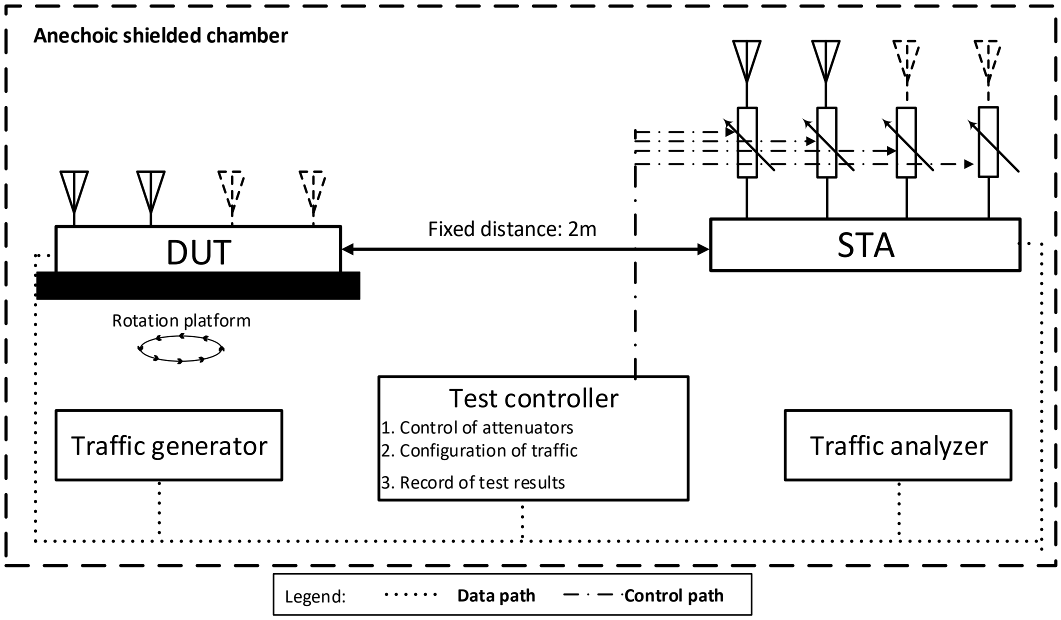

Figure 11: Test setup of Spatial Consistency Test

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 26: General configuration for spatial consistency 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. Additional attenuation for STA RF chain during the test:
   a) STA with strong signals: 10 dB @2.4GHz band, 10 dB @5GHz band;
   b) STA with medium signals: 38 dB @2.4GHz band, 25 dB @5GHz band;
   c) STA with weak signals: 48 dB @2.4 GHz band, 35 dB @5GHz band.

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. Increase the attenuation for each RF chain according to 6.3.2.3 and reset the position of DUT platform to 0°, until all the attenuation values have been tested. Repeat Step 2-5.
6. Set the working mode of DUT to 802.11ac with a bandwidth of 80 MHz and operating frequency to 5 GHz, reset the position of DUT platform to 0°. Repeat Step 2-5.
7. Set the working mode of DUT to 802.11ax over 2.4 GHz with a bandwidth of 20 MHz and reset the position of DUT platform to 0°. Repeat Step 2-5.
8. Set the working mode of DUT to 802.11ax over 5 GHz with a bandwidth of 80 MHz and reset the position of DUT platform to 0°. Repeat Step 2-5.

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 27 for at least 10 of the 12 measurement points (rotation angle) for each operating mode and attenuator setting.

Table 27: Pass/Fail criteria for spatial consistency test by performance

Wi-Fi configuration (DUT)	Wi-Fi configuration (Peer STA)	Bandwidth (MHz)	Throughput under different attenuation (Mbps)					
			Strong signals		Medium signals		Weak signals	
			DL	UL	DL	UL	DL	UL
802.11n (Nss=2)	802.11n (Nss=2)	20	90	90	70	70	35	35
802.11ac (Nss=2)	802.11ac (Nss=2)	80	500	500	TBD	TBD	TBD	TBD
802.11ax (2.4 GHz, Nss=2)	802.11ax (2.4 GHz, Nss=2)	20	150	150	100	100	35	35
802.11ax (5 GHz, Nss=2)	802.11ax (5 GHz, Nss=2)	80	700	700	400	400	200	200

b) The maximum variation during rotation SHALL satisfy the requirements in Table 28:

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 28: Pass/Fail criteria for spatial consistency test by variation

Wi-Fi configuration (DUT)	Wi-Fi configuration (Peer STA)	Bandwidth (MHz)	Variation under different attenuation (%)					
			Strong signals		Medium signals		Weak signals	
			DL	UL	DL	UL	DL	UL
11n (Nss=2)	11n (Nss=2)	20	30%	30%	30%	30%	30%	30%
11ac (Nss=2)	11ac (Nss=2)	80	40%	40%	40%	40%	40%	40%
802.11ax (2.4 GHz, Nss=2)	802.11ax (2.4 GHz, Nss=2)	20	30%	30%	30%	30%	30%	30%
802.11ax (5 GHz, Nss=2)	802.11ax (5 GHz, Nss=2)	80	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 MANDATORY for the test plan.

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 is put at a distance of 2 meters to the DUT (For 2.4 GHz band, 2 meter free space of wireless channel leads to 46 dB attenuation).
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 29: 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 (optional)	802.11ax, 5 GHz, Nss = 4, BW = 160 MHz
Config 4 (optional)	802.11ax, 5 GHz, Nss = 8, BW = 160 MHz
Configurations 3 and 4 SHALL be considered optional.	

6.3.3.4 Procedures

1. Configure the operating mode of the DUT and STA to the first configuration in Table 29.
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 29 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 includes only 1 Gbps Ethernet connections, the requirement for any metric exceeding 1 Gbps, such as Config 2, SHALL become 950 Mbps.

Table 30: 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 2 802.11ax, 5 GHz, Nss = 2, BW = 160 MHz	1100	1100
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
Notes: 1. These requirements are based on the 800 ns guard interval.		

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 MANDATORY for the test plan.

6.4.1.2 Setup

The same test setup shown in Figure 10 SHALL be used. Note the STA in Figure 10 is duplicated by 9 times in this test.

1. Total 9 STAs are engaged in the test. Three STAs are located in a short distance to the DUT. Three STAs are located in a medium distance to the DUT. The rest STAs are located in a long distance to the DUT. The short/medium/long distance are emulated by adding additional attenuation for the signals as follows:
   a) STA in short distance: 10 dB @2.4GHz band, 10 dB @5GHz band;

  b) STA in medium distance: 38 dB @2.4GHz band, 25 dB @5GHz band;
  c) STA in long distance: 48 dB @2.4 GHz band, 35 dB @5GHz band.
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.

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 31: 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.

6.4.1.4 Procedures

1. Configure DUT working mode as 802.11n, operating frequency band as 2.4GHz with default configuration.
2. Enable the radios on the STAs with the short 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 short distance. Record the result as “Throughput_S_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 short distance. Record the result as “Throughput_S_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 short distance and the three STA in medium distance). Record the result as “Throughput_SM_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 short distance and the three STA in medium distance). Record the result as “Throughput_SM_UL”.
5. Enable the radios on the STAs with the long 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 short distance, the three STA in medium distance and the three STA in long distance). Record the result as “Throughput_SML_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 short distance, the three STA in medium distance and the three STA in long distance). Record the result as “Throughput_SML_UL”.

6. Set the working mode of DUT to 802.11ac according to Table 31, and bandwidth to 80 MHz if applicable, and repeat Step 2- 5.
7. Set the working mode of DUT to 802.11ax over 2.4 GHz according to Table 31, and bandwidth to 20 MHz if applicable, and repeat Step 2- 5.
8. Set the working mode of DUT to 802.11ax over 5 GHz according to Table 31, and bandwidth to 80 MHz if applicable, and repeat Step 2- 5.

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.
Note 2: Distance MAY be simulated by using attenuators between RF output and antenna of Wi-Fi device.

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 32

Table 32: Throughput requirement of Multiple STAs Performance Test

Wi-Fi configuration (DUT)	Wi-Fi configuration (Peer STA)	Bandwidth (MHz)	Throughput_S (Mbps)		Throughput_SM (Mbps)		Throughput_SML (Mbps)	
			DL	UL	DL	UL	DL	UL
802.11n (Nss=2)	802.11n (Nss=2)	20	70	70	60	60	50	50
802.11ac (Nss=2)	802.11ac (Nss=2)	80	500	500	500	500	400	400
802.11ax (2.4 GHz, Nss=2)	802.11ax (2.4 GHz, Nss=2)	20	140	140	120	120	100	100
802.11ax (5 GHz, Nss=2)	802.11ax (5 GHz, Nss=2)	80	TBD	TBD	TBD	TBD	TBD	TBD

6.4.2 Multiple Association/Disassociation Stability Test

6.4.2.1 Introduction

Multiple association/disassociation stability test intends to measure 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 6) SHALL locate 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 in a short distance of 2 meter to the DUT (For 2.4 GHz band, 2 meter free space of wireless channel leads to 46 dB attenuation). The test is only conducted for one operating frequency band in each test circle.
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 33: 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.

6.4.2.4 Procedures

1. Configure the working mode of DUT as 802.11n, operating frequency as 2.4GHz 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 @2.4GHz and 8 Mbps @5GHz) from DUT to each STA.
3. Continue monitoring the traffic flow of each STA by recording the UDP flow rate every second.
4. Disassociate the rest peer STAs. Wait for 30 seconds. Re-associate the STAs simultaneously.
5. 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 2-4.
6. 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 2-4.

7. 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 2-4.

> **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:

a) The disassociation/association does not affect the performance of other peer STAs.
b) UDP traffic rate is at least 99% of the configured rate for each STA.
c) UDP packet loss rate SHALL be less than 0.01%.

6.4.3 Downlink MU-MIMO Performance Test

6.4.3.1 Introduction

Downlink MU-MIMO Performance Test intends to verify 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. The DUT SHALL support 802.11ac/ax MU-MIMO and at least 4 spatial streams.

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.

6.4.3.2 Setup

1. The test setup (see Figure 8) SHALL locate 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 maximum two spatial streams while two STAs (STA 2 and STA 3) support only one spatial stream. All STAs are located in the distance of 2 meter to the DUT (For 5.2 GHz band, 2-meter free space of wireless channel leads to 52.8 dB attenuation) and are placed at different angles relative to the DUT, ideally more than 45 degrees apart.
3. A Traffic Generator/Analyzer, sending the Ethernet packet to each peer STA, connects to the LAN interface of the DUT.
4. 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. 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:

a) 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.
b) 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 metrics SHALL only apply to the DUT that supports the configuration to disable DL MU-MIMO.

6.5 Stability/Robustness

6.5.1 Long Term Stability Test

6.5.1.1 Introduction

Long term stability test intends to measure 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 and 5 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. 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.
3. 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.
4. 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.
5. 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 and 802.11ax 5 GHz

If the DUT does not include multiple radios (i.e. the DUT does not support either the 2.4 or 5 GHz band), the test SHALL be run with only the single band in operation, with a total of 2 STAs.

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.
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. 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 or 5]_GHZ_INTERVAL_n, where the band is indicated as 2.4 or 5 GHz and n represents the n’th measurement interval. Calculate the PACKET_LOSS_RATIO_[24 or 5]_GHZ_INTERVAL_n as the number of lost packets divided by the total number of packets transmitted.
7. Repeat steps 4 and 5 for a total of 16 measurement intervals (4 hours of testing).
8. Repeat steps 1 through 6 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 intends to verify Wi-Fi device performance with existence of alien AP. The alien AP in the test SHALL support the same Wi-Fi standard (802.11n/802.11ac/802.11ax).

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.

6.5.2.2 Setup

1. The test setup (show in Figure 12) SHALL locate in the anechoic shielded chamber (see section 5.2.1 and 5.2.2), DUT and peer STA is in a distance of 2 meters.
2. 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.
3. The host SHALL send the Ethernet packets/IP packets at the maximum rate which the DUT can achieve theoretically.

4. 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 35. The QoS settings on the alien network SHALL match those on the DUT.
5. TCP connection SHALL be used for Ethernet packet transmission in the test.
6. 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 26 and the SSID that SHALL be set to " BBF_Wi-Fi_Perf_Test_Alien".

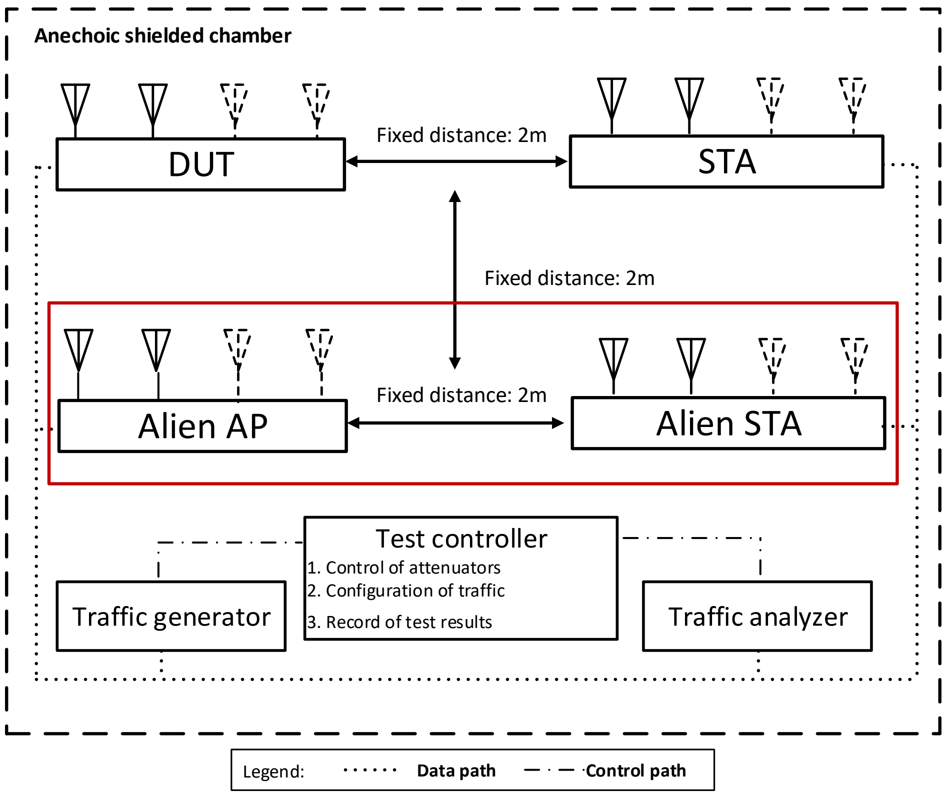

Figure 12: Test Setup of AP Coexistence Test

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 34: General configuration for AP coexistence 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 (5GHz, Nss=2)	802.11ax (5GHz, Nss=2)	80
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.

2. The alien network SHALL be set to different configurations:

Table 35: 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	36	36 (Note 2)	52

Notes:
1. 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.
2. 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).

6.5.2.4 Procedure

1. Configure the working mode of DUT to 802.11n, operating frequency band to 2.4 GHz with default configuration. Allow peer STA registers the DUT.
2. The channel of alien network SHALL be set to the same channel as DUT.
3. Keep the alien network radios shutdown (not transmitting any signals).
4. 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.
5. Enable the alien network radios. The alien network SHALL be configured according to Table 35. The alien network will transmit beacon frames according to the default configuration settings of 5.3.3.
6. 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.
7. Configure the alien network to utilize 50% of the available “air time”. This can be achieved by packet transmission using the alien network of 1500-byte packets at one of the following rates, depending on the configuration used for the alien network and the wireless MSC rate selected by the transmitter: 32 Mbps for 802.11n 20MHz channels with 1 spatial stream, 90 Mbps for 802.11ac 40MHz with 1 spatial stream, 195 Mbps for 802.11ac 80MHz with 1 spatial stream, 65 Mbps for 802.11n 20MHz channels with 2 spatial streams, 180 Mbps for 802.11ac 40MHz with 2 spatial streams, or 390 Mbps for 802.11ac 80MHz with 2 spatial streams.

8. 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.
9. Change the channel configuration of alien AP according to Table 35 until all the configuration has been tested. Repeat Step 8. Stop the packet transmission for alien network.
10. Shut down the radios on the alien network.
11. Repeat steps 2 to 10 for each additional configuration listed in Table 34 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:

a) The average throughput measured SHALL satisfy the requirements in Table 36:

Table 36 Pass/Fail criteria for AP coexistence test

Wi-Fi configuration (DUT)	**Wi-Fi configuration (Peer STA)**	**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)	802.11n (Nss=2)	20	-	<5%	<60 %	<60%	<5%
802.11ac (Nss=2)	802.11ac (Nss=2)	80	-	<5 %	<60 %	<60 %	<5 %
802.11ax (2.4 GHz, Nss=2)	802.11ax (2.4 GHz, Nss=2)	20	-	<5%	<60%	<60%	<5%
802.11ax (5 GHz, Nss=2)	802.11ax (5 GHz, Nss=2)	80	-	<5%	<60%	<60%	<5%
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 12) 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. Configure the DUT to enable automatic channel selection for both its 2.4 GHz and 5 GHz radios. Note, ensure these settings are persistently saved on the DUT.
3. 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.
4. Configure the additional AP to use 2.4 GHz Wi-Fi channel 6, 20 MHz channel bandwidth, and the settings in Table 37 below.
5. Configure the second station to associate to the additional AP using the settings in Table 37 below.
6. The Ethernet traffic generator / analyzer is connected to the additional AP and STA.

Table 37: 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	WPA2-Personal
Authentication Mode	WPA2-Personal
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 works in different modes:
   i. 802.11n
   ii. 802.11ac
   iii. 802.11ax over 2.4 GHz
   iv. 802.11ax over 5 GHz

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. The additional AP should be configured to use a channel bandwidth of 80 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 38: Automation 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 1, BW = 20 MHz	
3	2.4 GHz Channel 11, BW = 20 MHz	
4	5 GHz Channel 42, BW = 80 MHz	
5	5 GHz Channel 58, BW = 80 MHz	
6	5 GHz Channel 106, BW = 80 MHz	
7	5 GHz Channel 122, BW = 80 MHz	
8	2.4 GHz Channel 1, BW = 40 MHz	

Notes:

1. 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.

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 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).

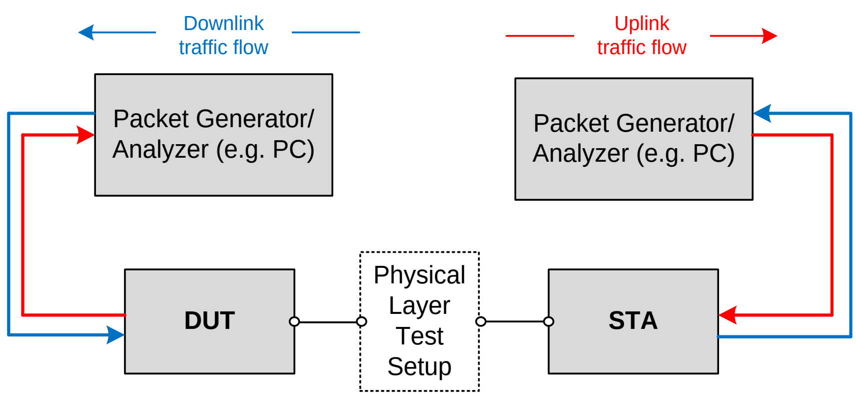

Figure 13: Test setup by using TCP/UDP flows with separate Packet Generator/Analyzer

Figure 13 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.

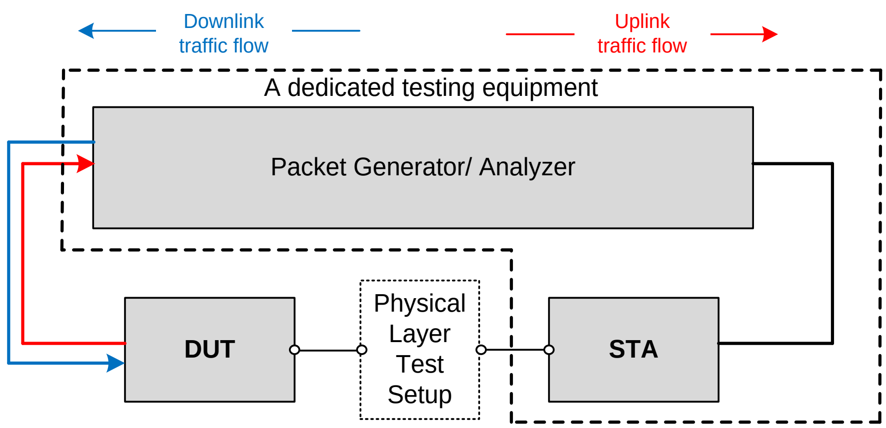

Figure 14: Test setup by using TCP/UDP flows with the dedicated testing equipment

Figure 14 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.

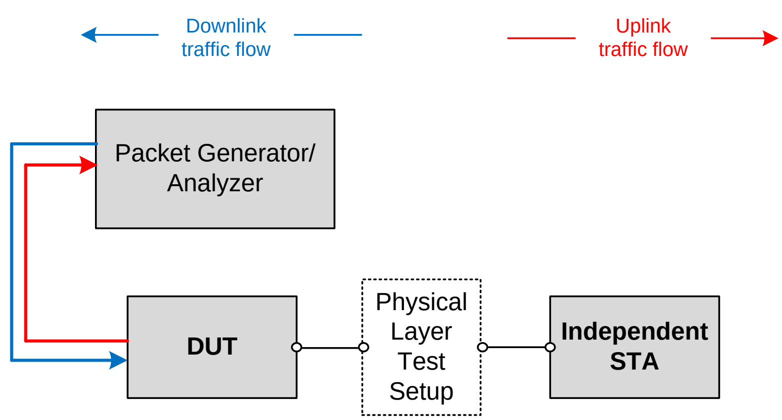

Figure 15: Test setup by using TCP/UDP flows with an independent STA

Figure 15 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 16 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.

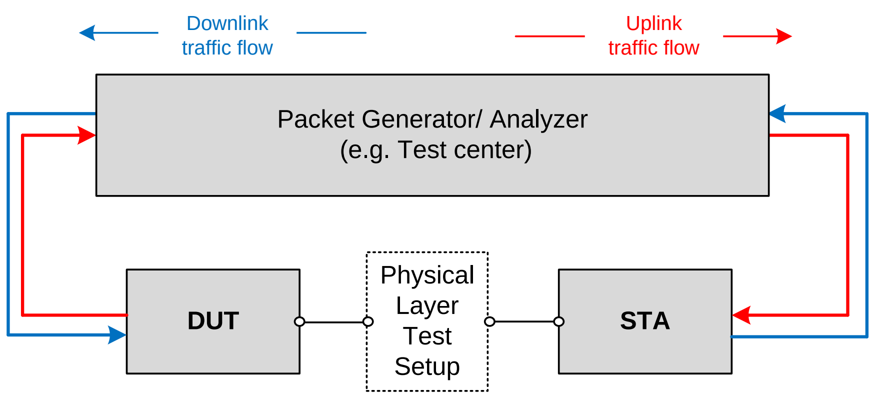

Figure 16: Test Setup by using level-2 Ethernet flows with a common Packet Generator/Analyzer

Appendix II. Test Cases For Further Study

The following test cases are optional and for further study. Specific pass / fail requirements for these cases may not yet be available. In these cases, testers are encouraged to provide the measurement data for information within test reports.

II.1 Repeated Wi-Fi Throughput Performance Test

II.1.1 Introduction

This test case measures the throughput performance of a Wi-Fi system, where the DUT is considered to be the combination of a "base AP" and a "Wi-Fi repeater." The "base AP" is defined as the AP devices connected to the wired network connection of the traffic generator and analyzer, while the "Wi-Fi repeater" has only RF connections to the both the "base AP" and the STA. During this test, the STA is only connected to the "Wi-Fi Repeater." The Wi-Fi connection between the "base AP" and "Wi-Fi repeater" 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 "base AP" and the "Wi-Fi Repeater" is expected to be at least 802.11ac Nss=2 or better in performance for this test.

This test SHALL be OPTIONAL for the test plan and is for further study.

II.1.2 Setup

1. The test setup shown in Figure 3 "Wi-Fi Mesh Multiple Chamber Implementation" SHALL be used for this test.
2. The "base AP" SHALL be placed in Shielded Chamber 1, and connected to the traffic generator.
3. The "Wi-Fi Repeater SHALL be placed in Shielded Chamber 2.
4. The Attn A set SHALL be configured to 10 dB.
5. The Attn B set SHALL be configured to 10 dB.
6. The Attn C set SHALL be configured to at least 60 dB.
7. The Traffic Generator/Analyzer, capable of sending the Ethernet packets, SHALL be connected to the LAN interface (e.g., GE port) of the "base AP" and the STA.
8. The Traffic Generator/Analyzer SHALL be configured to measure the throughput using TCP sessions.

II.1.3 DUT Configuration

The test SHALL be run with the STA configured for each of the operating modes listed in Table 39 below. For each configuration, a set of attenuation values for Attn B shall be measured.

Table 39: DUT configuration for Repeated Wi-Fi Throughput Performance Test

Wi-Fi Configuration	Configuration Description	Attn B Values (dB)
Config 1	802.11n, Nss = 2, BW = 20 MHz	10, 27, 36
Config 2	802.11ac, Nss = 2, BW = 80 MHz	10, 27, 36
Config 3	802.11ax 2.4 GHz, Nss = 2, BW = 20 MHz	10, 27, 36
Config 4	802.11ax 5 GHz, Nss = 2, BW = 80 MHz	10, 27, 36

II.1.4 Procedures

1. Configure the STA to operate in the first configuration mode described in Table 39.
2. Configure Attn B for the first value described in Table 39.
3. Establish the LAN connection and allow STA to associate with the DUT.
4. Measure the downlink TCP throughput to the STA, using a test time of 120 seconds.
5. Measure the uplink TCP throughput to the STA, using a test time of 120 seconds.
6. Repeat steps 2 through 5 for each attenuation value listed in Table 39 for the configured operating mode.
7. Repeat steps 1 through 6 for each configuration from Table 39 supported by the "Wi-Fi Repeater."

Note: The tester must ensure the STA is connected to the "Wi-Fi Repeater" and not the "Base AP" through Attn C.

II.1.5 Metrics (Pass/Fail Criteria)

1. For each attenuation configuration, the STA MUST be able to associate to the "Wi-Fi repeater."
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.

EDITOR'S NOTE: When developing the pass/fail metrics, the case should be considered where the back-haul link is 802.11ac Nss=2, while the front-haul link to the STA is 802.11ax Nss=2. This case will exist for some operators as systems roll out and should allow for those devices to pass.

Table 40: 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)**
10	For Further Studay	For Further Studay	For Further Studay	For Further Studay
27	For Further Studay	For Further Studay	For Further Studay	For Further Studay
36	For Further Studay	For Further Studay	For Further Studay	For Further Studay

Table 41: 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)**
10	For Further Studay	For Further Studay	For Further Studay	For Further Studay

27	For Further Study	For Further Study	For Further Study	For Further Study
36	For Further Study	For Further Study	For Further Study	For Further Study

Table 42: 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)**
10	For Further Study	For Further Study	For Further Study	For Further Study
27	For Further Study	For Further Study	For Further Study	For Further Study
36	For Further Study	For Further Study	For Further Study	For Further Study

Table 43: 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)**
10	For Further Study	For Further Study	For Further Study	For Further Study
27	For Further Study	For Further Study	For Further Study	For Further Study
36	For Further Study	For Further Study	For Further Study	For Further Study

II.2 Basic Roaming Performance Test

II.2.1 Introduction

This test case attempts to measure the roaming performance of the STA roaming between Wi-Fi connections of the “base AP” and the “Wi-Fi repeater.” The “base AP” is defined as the AP devices connected to the wired network connection of the traffic generator and analyzer, while the “Wi-Fi repeater” has only RF connections to the both the “base 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).

This test SHALL be OPTIONAL for the test plan and is for further study.

II.2.2 Setup

1. The test setup shown in Figure 3 “Wi-Fi Mesh Multiple Chamber Implementation” SHALL be used for this test.
2. The “base AP” SHALL be placed in Shielded Chamber 1, and connected to the traffic generator.

3. The “Wi-Fi Repeater SHALL be placed in Shielded Chamber 2.
4. The Attn A set SHALL be configured to 10 dB.
5. The Attn B set SHALL be configured to 10 dB.
6. The Attn C set SHALL be configured to 60 dB.
7. The Traffic Generator/Analyzer, capable of sending the Ethernet packets, SHALL be connected to the LAN interface (e.g., GE port) of the “base AP” and the STA.
8. The Ethernet traffic generator is configured to iperf3, or an equivalent substitute, to transmit one stream of 1460-byte UDP packets at 1 Mbps from the STA. The STA MUST NOT “buffer” packets while Wi-Fi is disconnected for the roaming event.
9. The STA SHALL have 802.11v (BSS Transition Management Messages) enabled. The DUT MAY, but is not required, to support 802.11v.

II.2.3 DUT Configuration

The test SHALL be run with the STA configured for each of the operating modes listed in Table 44 below.

Table 44: 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

II.2.4 Procedures

1. Configure the “base AP,” “Wi-Fi repeater,” and STA to operate in the first configuration mode described in Table 44. [Note 1]
2. Configure Attn B to 10 dB and Attn C to 60 dB.
3. Establish the LAN connection and allow STA to associate with the DUT. Verify the STA is associated with the “Wi-Fi repeater.”
4. Enable the uplink UDP transmission from the STA.
5. Decrease the value of Attn C by 1 dB
6. Wait 2 seconds
7. Increase the value of Attn B by 1 dB
8. Wait 2 second
9. Repeat steps 5 through 8 until Attn B is configured to 60 dB.
10. Stop the UDP transmission and record the number of UDP packets that were transmitted by the STA and the number of UDP packets received by the iperf target. [Note 2]
11. Restart the uplink UDP transmission from the STA.
12. Decrease the value of Attn B by 1 dB
13. Wait 2 seconds
14. Increase the value of Attn C by 1 dB
15. Wait 2 second
16. Repeat steps 5 through 8 until Attn C is configured to 60 dB.

17. Stop the UDP transmission and record the number of UDP packets that were transmitted by the STA and the number of UDP packets received by the iperf target. Note 2
18. Repeat steps 1 through 17 for each configuration from Table 44 supported by the "base AP" and "Wi-Fi repeater."

Notes:

1. The systems are configured to use a single wireless operating mode (i.e. 802.11n @ 2.4 GHz, Nss = 2, BW = 20 MHz), to reduce the measurement uncertainty between test runs, by preventing the case where the STA roamed from one AP to the other, while also changing operating modes.
2. 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 traffic.

II.2.5 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 then [value is For Further Study].

End of Broadband Forum Working Text WT-398i2