



WORKING TEXT

1
2
3
4
5
6
7
8
9
10
11
12
13

DRAFT
WIFIPERF-53

WT-398i2
Wi-Fi Residential & SOHO Performance Testing

Rev: 15
Rev Date: January 2021

14 **Notice**

15 The Broadband Forum is a non-profit corporation organized to create guidelines for broadband
16 network system development and deployment. This Working Text is a draft, is subject to change, and
17 has not been approved by members of the Forum. This Working Text is owned and copyrighted by
18 the Broadband Forum, and portions of this Working Text may be owned and/or copyrighted by
19 Broadband Forum members. This Working Text is only available to Broadband Forum Members and
20 Observers.

21 **Intellectual Property**

22 Recipients of this document are requested to submit, with their comments, notification of any relevant
23 patent claims or other intellectual property rights of which they may be aware that might be infringed
24 by any implementation of this Working Text if it were to be adopted as a Technical Report, and to
25 provide supporting documentation.

26 **Terms of Use**

27
28 Recipients of this document may use it only for internal review and study purposes, and to provide to
29 the Broadband Forum the comments and notification requested in the preceding paragraph. Any other
30 use of this Working Text is expressly prohibited without the prior written consent of the Broadband
31 Forum.

32
33 THIS Working Text IS BEING OFFERED WITHOUT ANY WARRANTY WHATSOEVER, AND
34 IN PARTICULAR, ANY WARRANTY OF NONINFRINGEMENT AND ANY IMPLIED
35 WARRANTIES ARE EXPRESSLY DISCLAIMED. ANY USE OF THIS Working Text SHALL
36 BE MADE ENTIRELY AT THE USER'S OR IMPLEMENTER'S OWN RISK, AND NEITHER
37 THE FORUM, NOR ANY OF ITS MEMBERS OR SUBMITTERS, SHALL HAVE ANY
38 LIABILITY WHATSOEVER TO ANY USER, IMPLEMENTER, OR THIRD PARTY FOR ANY
39 DAMAGES OF ANY NATURE WHATSOEVER, DIRECTLY OR INDIRECTLY, ARISING
40 FROM THE USE OF THIS Working Text, INCLUDING BUT NOT LIMITED TO, ANY
41 CONSEQUENTIAL, SPECIAL, PUNITIVE, INCIDENTAL, AND INDIRECT DAMAGES.

42
43 All copies of the Working Text (or any portion hereof) must include the notices, legends, and other
44 provisions set forth on this page.

45

46 **Rev History**

47

Rev Number	Date	Rev Editor	Changes
15	January 11, 2020	Lincoln Lavoie	<ul style="list-style-type: none"> • Output of the January 11, 2020 teleconference.
14	January 8, 2020	Lincoln Lavoie, UNH-IOL	<ul style="list-style-type: none"> • Implemented proposed pass/fail metrics for 2020-Q4 meeting.
13	November 25, 2020	Lincoln Lavoie, UNH-IOL	<ul style="list-style-type: none"> • Final straw ballot comment resolutions from October 26 teleconference.
12	October 12, 2020	Lincoln Lavoie, UNH-IOL	<ul style="list-style-type: none"> • Straw ballot editorial comment resolutions.
11	July 27, 2020	Lincoln Lavoie	<ul style="list-style-type: none"> • Editorial updates and clean up. • Added WIFIPERF-81
10	July 20, 2020	Lincoln Lavoie	<ul style="list-style-type: none"> • Editorial updates and clean up. • Implemented agreements from July 20 teleconference. • Added WIFIPERF-63 • Added WIFIPERF-70
09	July 17, 2020	Lincoln Lavoie	<ul style="list-style-type: none"> • Added WIFIPERF-76 • Added WIFIPERF-57 • Added WIFIPERF-75 • Addressed some of the editor notes of for 802.11ax cases.
08	July 5, 2020	Lincoln Lavoie, UNH-IOL	<ul style="list-style-type: none"> • Updated based on Q2 meeting. • Added WIFIPERF-79.
07	May 11, 2020	Lincoln Lavoie, UNH-IOL	<ul style="list-style-type: none"> • Updated based on the May 11, 2020 teleconference
06	March 24, 2020	Lincoln Lavoie, UNH-IOL	<ul style="list-style-type: none"> • 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.
05	March 18, 2020	Lincoln Lavoie, UNH-IOL	<ul style="list-style-type: none"> • Updated based on the agreements from the 2020-

			Q1 face-to-face meeting (WIFIPERF-71, WIFIPERF-74)
04	January 8, 2020	Lincoln Lavoie, UNH-IOL	<ul style="list-style-type: none"> Updated based on agreements from the 2019-Q4 face-to-face meeting (WIFIPERF-66)
02	September 17, 2019	Lincoln Lavoie, UNH-IOL	<ul style="list-style-type: none"> Updated based on agreements from 2019-Q3 face-to-face meeting (WIFIPERF-52, WIFIPERF-56, WIFIPERF-58, WIFIPERF-60).
01	August 20, 2019	Lincoln Lavoie, UNH-IOL	<ul style="list-style-type: none"> Updated based on agreements from July 29 teleconference.
00	July 29, 2019	Lincoln Lavoie, UNH-IOL	<ul style="list-style-type: none"> Baseline text from TR-398 Issue 1. Changes from TR-398i1c1 applied to Table 15

48
49
50
51
52
53

Comments or questions about this Broadband Forum Working Text should be directed to info@broadband-forum.org.

Editors	Lincoln Lavoie	UNH-IOL	lylavoie@iol.unh.edu
	Evan Sun	Huawei	evan.sun@huawei.com
Work Area Director(s)	Jason Walls	QA Cafe	jason@qacafe.com
	John Blackford	Commscope	john.blackford@commscope.com
	Herman Verbueken	Nokia	herman.verbueken@nokia.com

54
55
56

57 **Table of Contents**

58 1 Purpose and Scope 10

59 1.1 Purpose 10

60 1.2 Scope 10

61 2 References and Terminology 12

62 2.1 Conventions 12

63 2.2 References 12

64 2.3 Definitions 13

65 2.4 Abbreviations 13

66 3 Working Text Impact 15

67 3.1 Energy Efficiency 15

68 3.2 Security 15

69 3.3 Privacy 15

70 4 Equipment Features 16

71 4.1 Device Under Test (DUT) and Station (STA) 16

72 4.1.1 Device Information 16

73 4.1.2 Management of the DUT and STA 16

74 4.2 Testing Equipment and Components 17

75 5 Test Environment 18

76 5.1 Test Configuration 18

77 5.1.1 Ethernet/IP Traffic Setup 18

78 5.1.2 Ethernet Traffic Flow Generation 19

79 5.1.3 Example: Ethernet traffic generation by iPerf3 20

80 5.2 Test Setup Characteristics 21

81 5.2.1 Shielded Test Chamber 22

82 5.2.2 Distance and Test Channel Realization 22

83 5.2.3 STA Requirements 26

84 5.3 Device Under Test (DUT) settings 27

85 5.3.1 DUT Requirements 27

86 5.3.2 SSID setting 27

87 5.3.3 Radio interface settings 28

88 6 Performance Tests 32

89 6.1 RF capability 32

90 6.1.1 Receiver Sensitivity Test 32

91 6.2 Baseline performance 35

92 6.2.1 Maximum Connection Test 36

93 6.2.2 Maximum Throughput Test 37

94 6.2.3 Airtime Fairness Test 39

95 6.2.4 Dual-band Throughput Test 43

96 6.2.5 Bidirectional Throughput Test 46

97 6.3 Coverage 47

98 6.3.1 Range Versus Rate Test..... 48

99 6.3.2 Spatial consistency test..... 51

100 6.3.3 802.11ax Peak Performance Test..... 54

101 6.4 Multiple STAs Performance..... 56

102 6.4.1 Multiple STAs Performance Test..... 56

103 6.4.2 Multiple Association/Disassociation Stability Test..... 58

104 6.4.3 Downlink MU-MIMO Performance Test 60

105 6.5 Stability/Robustness 61

106 6.5.1 Long Term Stability Test 62

107 6.5.2 AP Coexistence Test 63

108 6.5.3 Automatic Channel Selection Test..... 66

109 Appendix I. Instantiations of Test Setups 69

110 I.1 Test setup by using IP packet through TCP or UDP 69

111 I.2 Test Setup by Using Level-2 Ethernet Packet..... 70

112 Appendix II. Test Cases For Further Study 72

113 II.1 Repeated Wi-Fi Throughput Performance Test 72

114 II.1.1 Introduction..... 72

115 II.1.2 Setup..... 72

116 II.1.3 DUT Configuration 72

117 II.1.4 Procedures 73

118 II.1.5 Metrics (Pass/Fail Criteria)..... 73

119 II.2 Basic Roaming Performance Test 74

120 II.2.1 Introduction..... 74

121 II.2.2 Setup..... 74

122 II.2.3 DUT Configuration 75

123 II.2.4 Procedures 75

124 II.2.5 Metrics (Pass/Fail Criteria)..... 76

125

126

127 **List of Figures**
 128
 129 Figure 1: Test setup for performance testing for single STA..... 19
 130 Figure 2: Single Chamber Implementation 24
 131 Figure 3: Multiple Chamber Implementation..... 25
 132 Figure 4: Wi-Fi Mesh Multiple Chamber Implementation 26
 133 Figure 5: Test Setup for Receiver Sensitivity 33
 134 Figure 6: Test setup of Maximum Connection Test..... 36
 135 Figure 7: Test setup of Maximum Throughput Test 38
 136 Figure 8: Test setup of Airtime Fairness Test 40
 137 Figure 9: Test setup Dual-band Throughput Test 44
 138 Figure 10: Test setup of Range Versus Rate Test 49
 139 Figure 11: Test setup of Spatial Consistency Test 52
 140 Figure 12: Test Setup of AP Coexistence Test 64
 141 Figure 13: Test setup by using TCP/UDP flows with separate Packet Generator/Analyzer 69
 142 Figure 14: Test setup by using TCP/UDP flows with the dedicated testing equipment 70
 143 Figure 15: Test setup by using TCP/UDP flows with an independent STA 70
 144 Figure 16: Test Setup by using level-2 Ethernet flows with a common Packet Generator/Analyzer 71
 145
 146 **List of Tables**
 147
 148 Table 1: DUT Information 16
 149 Table 2: STA Information 16
 150 Table 3: Traffic Generator/Analyzer Information..... 17
 151 Table 4: Attenuator Information 17
 152 Table 5: Test Chamber Information 17
 153 Table 6: Additional Antenna Information 17
 154 Table 7: Temperature and Humidity Range of Test Facility 22
 155 Table 8: SSID setting configuration..... 27
 156 Table 9: Work setting configuration for 802.11n 2.4 GHz band 29
 157 Table 10: Work setting configuration for 802.11ac 5 GHz band..... 30
 158 Table 11: Work setting configuration for 802.11ax (2.4 & 5 GHz band)..... 30
 159 Table 12: Wi-Fi Test Configurations for Receiver Sensitivity 33
 160 Table 13: MCS and Traffic Test Configuration for 802.11n 34
 161 Table 14: MCS and Traffic Test Configuration for 802.11ac..... 34
 162 Table 15: MCS and Traffic Test Configuration for 802.11ax 2.4 GHz 34
 163 Table 16: MCS and Traffic Test Configuration for 802.11ax 5 GHz 34
 164 Table 17: Required Receiver Sensitivity for 802.11n 35
 165 Table 18: Required Receiver Sensitivity for 802.11ac 35
 166 Table 19: Required Receiver Sensitivity for 802.11ax 2.4 GHz..... 35
 167 Table 20: Required Receiver Sensitivity for 802.11ax 5 GHz..... 35
 168 Table 21: The Throughput Requirement 39
 169 Table 22: Dual-band Throughput Test Requirements 45
 170 Table 23: Bidirectional Throughput Test Requirements 47
 171 Table 24: General configuration for range vs rate test..... 49
 172 Table 25: Additional attenuation for STA RF chain during the test 49

173	Table 26: The throughput requirement.....	50
174	Table 27: General configuration for spatial consistency test	52
175	Table 28: Pass/Fail criteria for spatial consistency test by performance	53
176	Table 29: Pass/Fail criteria for spatial consistency test by variation	54
177	Table 30: Wi-Fi configuration for 802.11ax Peak Performance Test	54
178	Table 31: 802.11ax Peak Performance Throughput Requirements.....	55
179	Table 38: DUT configuration for Multiple Association / Disassociation Stability Test.....	57
180	Table 39: Throughput requirement of Multiple STAs Performance Test	58
181	Table 40: DUT configuration for Multiple Association / Disassociation Stability Test.....	59
182	Table 41: General configuration for AP coexistence test.....	64
183	Table 42: Channel configuration in the test	65
184	Table 43 Pass/Fail criteria for AP coexistence test	66
185	Table 44: SSID configuration for adjacent network	67
186	Table 45: Automation Channel Selection Test Requirements	68
187	Table 32: DUT configuration for Repeated Wi-Fi Throughput Performance Test.....	72
188	Table 33: Pass/Fail requirements for Repeated Wi-Fi Throughput Performance Test Config 1	73
189	Table 34: Pass/Fail requirements for Repeated Wi-Fi Throughput Performance Test Config 2	73
190	Table 35: Pass/Fail requirements for Repeated Wi-Fi Throughput Performance Test Config 3	74
191	Table 36: Pass/Fail requirements for Repeated Wi-Fi Throughput Performance Test Config 4	74
192	Table 37: DUT configuration for Basic Roaming Performance Test	75
193		

194 Executive Summary

195

196 TR-398 provides a set of performance test cases with pass/fail requirements for 802.11n/ac/ax
197 implementations according to Institute of Electrical and Electronics Engineers (IEEE) specification
198 802.11ac [1].

199

200 The primary goal of WT-398i2 is to provide a standard set of test cases and framework to measure
201 aspect of the performance between Access Point (AP) (e.g., a CPE with Wi-Fi), one or more
202 references Station (STA) (e.g., Personal Computer [PC], integrated testing equipment, etc.), and if
203 applicable, one Wi-Fi repeater, under controlled laboratory conditions. The test cases are defined for
204 a Device Under Test (DUT – AP only), tested against a or a set of STA.

205

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

208

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

211

212

213 1 Purpose and Scope

214 1.1 Purpose

215 WT-398i2 provides a set of performance test cases with pass/fail requirements for 802.11n/ac/ax
216 implementations, to assist operators in the selection of Wi-Fi capable devices. Operators will use
217 additional criteria, such as deployment scenarios, customer needs, complexity, when selecting
218 equipment and defining deployment configurations. These test cases are not suitable for consumer
219 selection of devices in the absence of expert level understanding of Wi-Fi operation, configurations,
220 and deployment scenarios. The corresponding certification programs of interoperability are “Wi-Fi 4”
221 “Wi-Fi 5”, and “Wi-Fi 6” for 802.11n, 802.11ac, and 802.11ax in Wi-Fi Alliance, respectively.
222

223 The primary goal of WT-398i2 Rev 15 is to provide a standard set of test cases and framework to
224 measure aspects of the performance between AP (e.g., a CPE with Wi-Fi), one or more reference STA
225 (e.g., PC, integrated testing equipment, etc.), and if applicable, one Wi-Fi repeater, under controlled
226 laboratory conditions. The test cases are defined for a Device Under Test (DUT – AP only), tested
227 against a or a set of STA. The DUT SHOULD NOT be a reference design and SHOULD contain the
228 necessary system functionality to execute this test plan (see section 5)
229

230 Technical content in this test plan includes test setup information, equipment configuration
231 requirements, test procedures, and pass/fail requirements for each test case. Specific manufacturer
232 information for test and measurement has not been included in this document, except in cases where
233 the selection or use of alternate equipment could negatively impact the results of the testing.
234

235 1.2 Scope

236 This Technical Report intends to provide a performance test plan for “IEEE standard for Information
237 technology-Telecommunications and information exchange between systems Local and metropolitan
238 area networks- Specific requirements Part 11: Wireless LAN Medium Access Control (MAC) and
239 Physical Layer (PHY) Specifications specification”. WT-398i2 Rev 15 is specifically developed for
240 802.11n/ac/ax compliant access point devices. The performance of Wi-Fi station (STA) is not in the
241 scope of this project.
242

243 Wi-Fi Access Point devices are used in a wide variety of premises which contain many elements
244 which will influence Wi-Fi performance. WT-398i2 Rev 15 is intended to address a generalized set
245 of performance test cases performed in a controlled laboratory environment. The performance test
246 cases are intended for the access point, to verify:
247

- 248 1) RF capability
- 249 2) Throughput performance
- 250 3) Spatial consistency
- 251 4) Airtime fairness
- 252 5) Connection capability
- 253 6) Stability/Robustness

254

- 255 Issue 2 of this test plan makes the following changes and provides the listed additional tests:
- 256
- 257
- 258
- 259
- 260
- 261
- 262
- 263
- 264
- 265
- 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”

266 **2 References and Terminology**

267 **2.1 Conventions**

268 In this Working Text, several words are used to signify the requirements of the specification. These
 269 words are always capitalized. More information can be found be in RFC 2119 [2].
 270

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.

271

272 **2.2 References**

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

277

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

280

Document	Title	Source	Year
[1] 802.11	<i>IEEE standard for Information technology- Telecommunications and information exchange between systems Local and metropolitan area networks- Specific requirements Part 11: Wireless LAN Medium Access Control (MAC)</i>	IETF	2016

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

281
 282 **EDITOR’S NOTE:** 802.11ax is still a draft (until November), how to reference this update, or
 283 should we just reference 802.11 in general, if so, what date to use?

284 **2.3 Definitions**

285 The following terminology is used throughout this Working Text.

- 286
- 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.

287

288 **2.4 Abbreviations**

289 This Working Text uses the following abbreviations:

290

- 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

291
292
293

294 **3 Working Text Impact**

295 **3.1 Energy Efficiency**

296 TR-398 has no impact on Energy Efficiency.

297 **3.2 Security**

298 TR-398 has no impact on Security.

299 **3.3 Privacy**

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

301

302

303 **4 Equipment Features**

304 **4.1 Device Under Test (DUT) and Station (STA)**

305 **4.1.1 Device Information**

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

312 **Table 1: DUT Information**

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

314 **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).	

316
317

318 **4.1.2 Management of the DUT and STA**

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

322
 323 The STA SHALL support a STA Southbound management protocol that is required for execution of
 324 this test plan except as required to configure the STA to pass Ethernet traffic between the STA and
 325 Local Area Network (LAN) interface(s).

326

327 **4.2 Testing Equipment and Components**

328 This section includes tables to record information of testing equipment and components that are used
 329 in the test. The information defined in the tables SHALL be provided to the test engineer prior to the
 330 start of the testing and SHALL be included as part of the test report. All fields SHALL be populated;
 331 if an item is not applicable to the DUT or connected STAs, the item MAY be marked as “Not
 332 Applicable” .
 333

334 **Table 3: Traffic Generator/Analyzer Information**

Manufacturer	
Equipment model	
Code version	

335 **Table 4: Attenuator Information**

336

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

337 **Table 5: Test Chamber Information**

338

Manufacturer	
Equipment model	

339 **Table 6: Additional Antenna Information**

340

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

341
 342

343 **5 Test Environment**

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

349 **5.1 Test Configuration**

350 **5.1.1 Ethernet/IP Traffic Setup**

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

357
358 If the test case requires test traffic larger than 1 Gbps at the LAN interface, multiple Gigabit Ethernet
359 ports SHALL be employed to fulfill the test traffic demand in the test. In this case, identical traffic
360 streams with same Quality of Service (QoS) setting SHALL be injected to Gigabit Ethernet ports,
361 respectively.

362
363 If the DUT supports Ethernet port with higher rate than 1Gbps (e.g., 2.5G, 5G, or 10G Ethernet, etc.),
364 no additional port is used in the testing.

365
366 Figure 1 shows the basic setup for passing Ethernet/IP traffic through the DUT and single STA.
367 Appendix I shows the instantiations of the test setups. The Packet Generator/Analyzer MAY be a
368 discrete device from the STA, or the Packet Generator/Analyzer may be embedded directly on the
369 STA device. The Packet Generator/Analyzer SHALL NOT be combined with the DUT and SHALL
370 be a discrete device running the testing software to generate/receive the packets for DUT.

371
372 **Note:** The Physical Layer Test Setup shown in Figure 1 contains any specific test setup(s) or equipment that may
373 be required within the Wi-Fi link, such as a channel simulator, attenuators, etc.

374

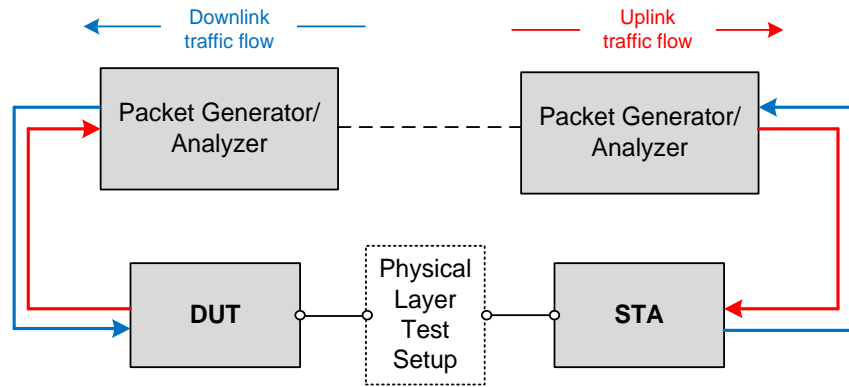


Figure 1: Test setup for performance testing for single STA

375
376
377
378
379
380
381
382
383
384
385
386
387
388
389
390

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.

391 **5.1.2 Ethernet Traffic Flow Generation**

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

395
396 Where the Packet Generator/Analyzer is used to implement the traffic throughout measurements
397 within this test plan, the following settings SHALL be used to configure the traffic generator. All
398 throughput measurements SHALL be the layer 4 (payload rate) for the TCP or UDP traffic streams.

- 401 ● Common setting for both TCP and UDP:
 - 402 a) Establish TCP/UDP link through IP pairing before generation of traffic flow, i.e., setting up the
403 IP address of DUT and STA to make sure that all of the devices are in the same LAN.
 - 404 b) The flow generation SHALL be based on IPv4.
 - 405 c) Create 10 and 1 measurement streams between DUT and each STA for TCP and UDP,
406 respectively. The throughput between the DUT and STA is the summation of all the measurement
407 streams.

- 408 d) No rate limitation SHALL be set for the TCP/UDP flow.
409 e) The data sent over the TCP SHALL be a randomized byte stream.
410
411 ● Setting for TCP:
412 a) TCP window size SHALL be set as 64KB.
413 b) A code file (file size of 100000 bytes for 2.4GHz testing and 10000000 bytes for 5 GHZ testing)
414 transaction SHALL be simulated in the TCP connection. This transaction SHALL be
415 continuously conducted during the measurement time. The code file shall be a constructed of
416 randomized bytes.
417 c) Each fragment of the file is sent continuously to operating system running the test software. The
418 d) TCP payload size SHOULD be determined by the operating system.
419
420 ● Setting for UDP:
421 a) A code file (file size of 730000) transaction SHALL be simulated in the UDP connection. This
422 transaction SHALL be continuously conducted during the measurement time. The code file shall
423 be a constructed of randomized bytes.
424 b) The UDP payload size SHALL be set as 1460 bytes.
425 **Note:** This leads to 1472 bytes Ethernet frame size. The size of the transmitted data is 1460 bytes with 20-bytes IPv4
426 header and 8-byte UDP header.
427

428 5.1.3 Example: Ethernet traffic generation by iPerf3

429 Where the open source program iPerf3 is used to implement the traffic throughout measurements
430 within this test plan, a predetermined set of command line flags SHALL be used to start and run the
431 iPerf3 program as documented below, unless a specific test case provides alternate commands, to
432 ensure consistency within testing.
433

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

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

441
442 Specific client commands for each test scenario are located below. An explanation of the commands
443 follows, for information only.
444

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

446
447 TEST_TIME is the length of time the measurement will run for. This is set within each test case
448 below.
449

450 The *bitrate* parameter is set to zero, to instruct iPerf3 to attempt to determine (measure) the maximum
451 throughput between the client and server.
452

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

456
457 The *reverse* parameter instructs iPerf3 to measure the bandwidth from the server to the client. The
458 default behaviour performs the measurement from the client to the server.

459
460 The *udp* parameter instructs iPerf3 to use the UDP transport instead of the default TCP transport.

461
462 The *omit 2* parameter instructs iPerf3 to “discard” the first 2 seconds of the measurement, to avoid
463 inclusion of TCP slow start, etc.

464
465 Additional commands MAY be used to alter/direct logging or format of results, such as the *--logfile*
466 or *--json* options. However, any additional command SHALL NOT alter the operation or
467 measurement traffic used by the program.

468
469 The iPerf3 programs SHALL be run on a Linux based system, using a kernel version of 4.14 or newer.
470 The system SHALL include at least one processor, with two cores, of at least 2 GHz.

471 **5.1.3.1 Commands for iPerf3**

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

475 **5.1.3.1.1 TCP Unidirectional Traffic Throughput Measurement**

476
477 *iPerf3 --client <SERVER_IP> --time <TEST_TIME> --bitrate 0 --parallel 10 --reverse --omit 2*
478

479 **5.1.3.1.2 UDP Unidirectional Traffic Throughput Measurement**

480
481 *iPerf3 --client <SERVER_IP> --time <TEST_TIME> --bitrate <BITRATE> --reverse --udp --omit*
482 *2*
483

484 **5.1.3.1.3 Bidirectional Traffic Throughput Measurements**

485 For tests requiring bidirectional traffic throughput measurements, the *--reverse* flag is omitted and
486 the *--bidir* flag is added. The change is applied to either the above TCP or UDP commands as need.
487

488 **5.2 Test Setup Characteristics**

489 Test results obtained as a result of testing performed in accordance with WT-398i2 SHALL contain
 490 the information described in sections 5.2.1.
 491

492 **5.2.1 Shielded Test Chamber**

493 Several tests specify an anechoic shielded chamber environment. Within this test environment, the
 494 ambient noise plus signal power, in the absence of the DUT and its Wi-Fi clients, SHALL be less
 495 than -100 dBm across the 80 MHz bandwidth at the working channel frequency, as measured by a
 496 spectrum analyzer with its resolution bandwidth set so it has the noise floor no more than -103dBm.
 497 This condition guarantees no false back off or contention take place and facilitates the correct
 498 performance measurement in extreme cases (e.g., performance testing with large attenuation).
 499

500 **5.2.1.1 Temperature and Humidity**

501 The ranges of temperature and humidity of the test facility, over the entire time tests are conducted,
 502 SHALL be recorded as the high and low values observed during testing (see Table 7) and SHALL
 503 be included as part of the test report. The temperature SHOULD be within 21 ± 5 °C. The relative
 504 humidity SHOULD be between 20% and 60%.
 505
 506

Table 7: Temperature and Humidity Range of Test Facility

Parameter	High	Low
Temperature		
Relative Humidity		

507

508 **5.2.2 Distance and Test Channel Realization**

509 To facilitate repeatable testing and support the application of absolute performance requirements, the
 510 wireless channel between the DUT and STA(s) needs to be well controlled. The test setup
 511 implemented SHALL meet the requirements within this section. Various methods to create and
 512 control this environment exist and MAY be used for the support of the testing defined in this
 513 document, provided the test setup implemented meets the requirements within sections.
 514

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

- 518 a. If distance is used, then the peer STA SHALL be placed at the same height as the DUT.
 519 Additionally, the test report SHALL indicate the rotational orientation of both the STA and
 520 DUT. Both STA and DUT SHALL be placed in their “upright” position, as defined by the
 521 manufacturers.
- 522 b. If external antenna is used, the antenna SHALL be adjusted perpendicularly to the horizontal
 523 plane.

- 524 c. If path-loss is used, then the peer STA SHALL be separated from the DUT by the equivalent
525 free space path loss at the working frequency. Free space path loss between isotropic antennas
526 is expressed as $P_L (dB) = 20 \text{Log}_{10}(f_GHz) + 20 \text{Log}_{10}(d_meters) + 32.45$. For example, at
527 2.4 GHz the path loss equivalent to a 1-meter separation is 40 dB, and at 5.2 GHz the path
528 loss is 46.8 dB. The attenuation value for testing SHALL be rounded to the nearest whole dB
529 value.
- 530 d. A channel emulator (e.g., test equipment) MAY be used to implement the test channel.
- 531 e. If the test channel is created using attenuators or a channel emulator, the test equipment
532 SHALL support at least the same number of independent channels as the number of spatial
533 streams being tested.
- 534 f. The attenuators used to create signal attenuation SHALL perform flat attenuation in the
535 frequency bandwidth.
- 536

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

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

541

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

547

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

551

552 **5.2.2.1 Single Chamber Implementation**

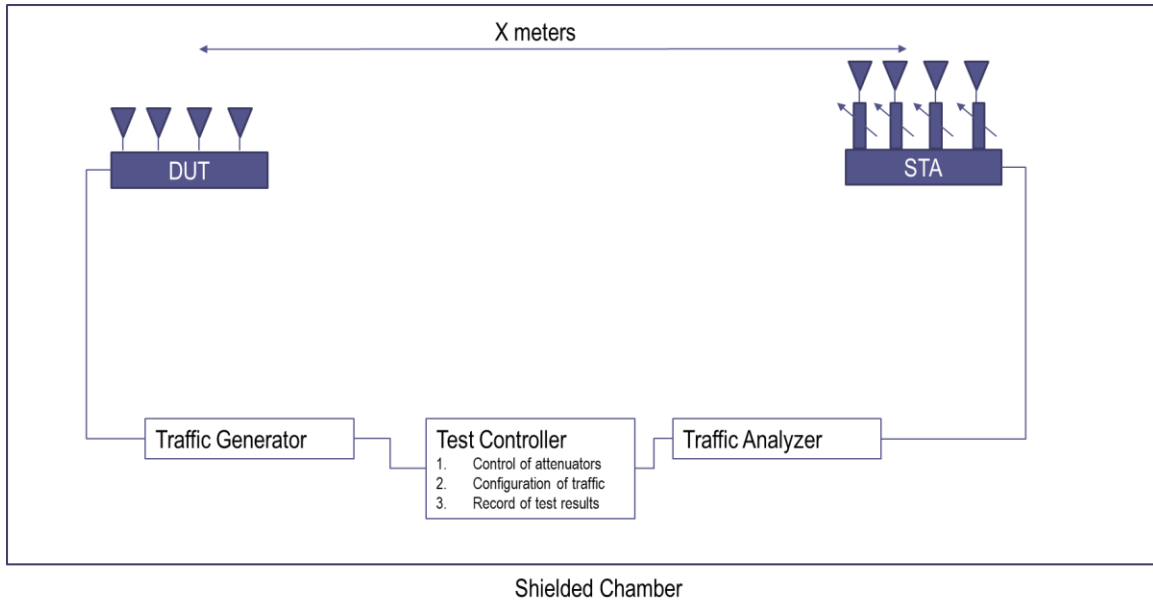
553 In a single chamber implementation of the test environment, there is a single shielded chamber used
554 to provide the interference-free environment, and physical separation is used to provide path-loss
555 between devices. For path-loss modification, attenuators are placed on the STA antenna ports. Note
556 that one difficulty in this implementation is in gaining access to the STA antenna ports, which will
557 not be possible with all STAs.

558

559 In this implementation, it is anticipated the single chamber provides the required shielding to meeting
560 the ingress noise requirements. The chamber SHALL be large enough to meet the spacing
561 requirements defined in each test case.

562

563



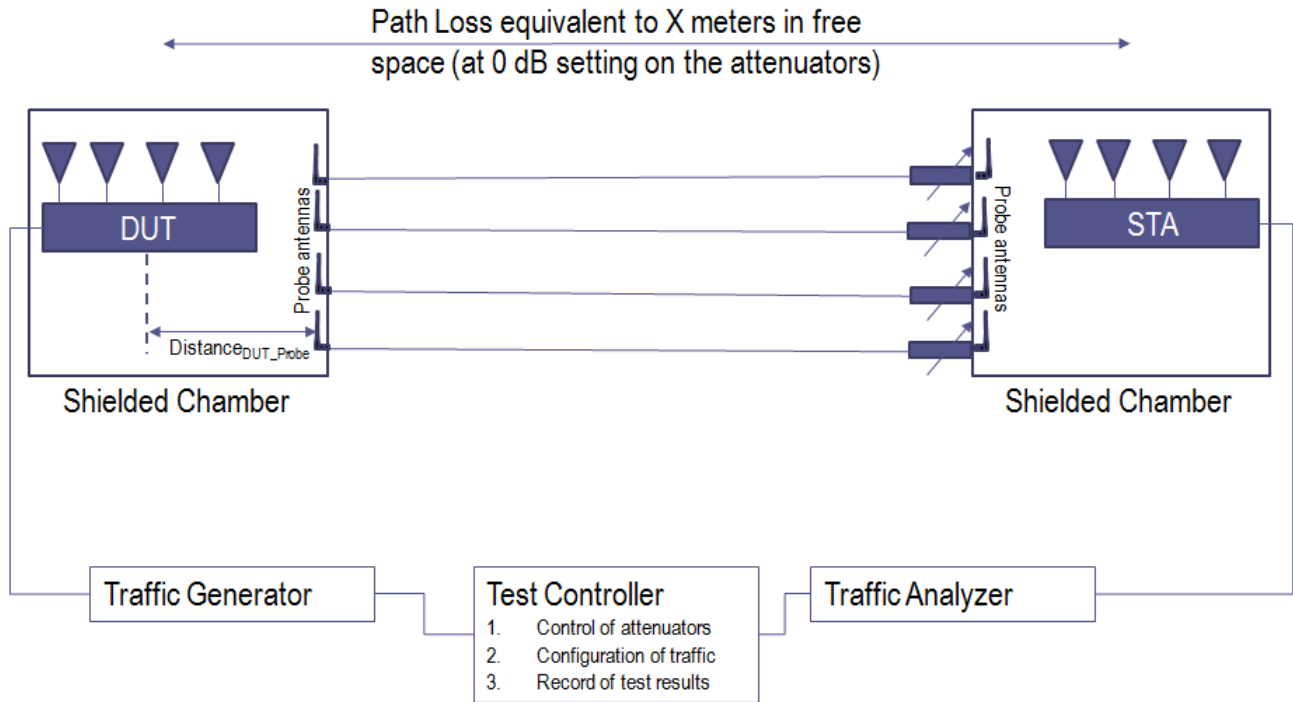
564
565

Figure 2: Single Chamber Implementation

566 **5.2.2.2 Multiple Chamber Implementation**

567 In a multiple chamber implementation of the test environment, there are multiple chambers used to
 568 provide the interference-free environment. The RF separation between the devices is composed of
 569 the free-space path-loss inside the chambers, the RF cabling that connects the boxes, and the variable
 570 attenuation. Note that in this implementation the variable attenuation is available without access to
 571 the DUT or STA antenna ports. Additionally, a channel fader, or multi-path emulator, can also be
 572 inserted into the RF cable path to better align the test results with those observed in a purely free
 573 space environment. The distance ($Distance_{DUT_Probe}$) between the probe antennas and the DUT/STA
 574 SHALL be less than 0.5 meter.

575

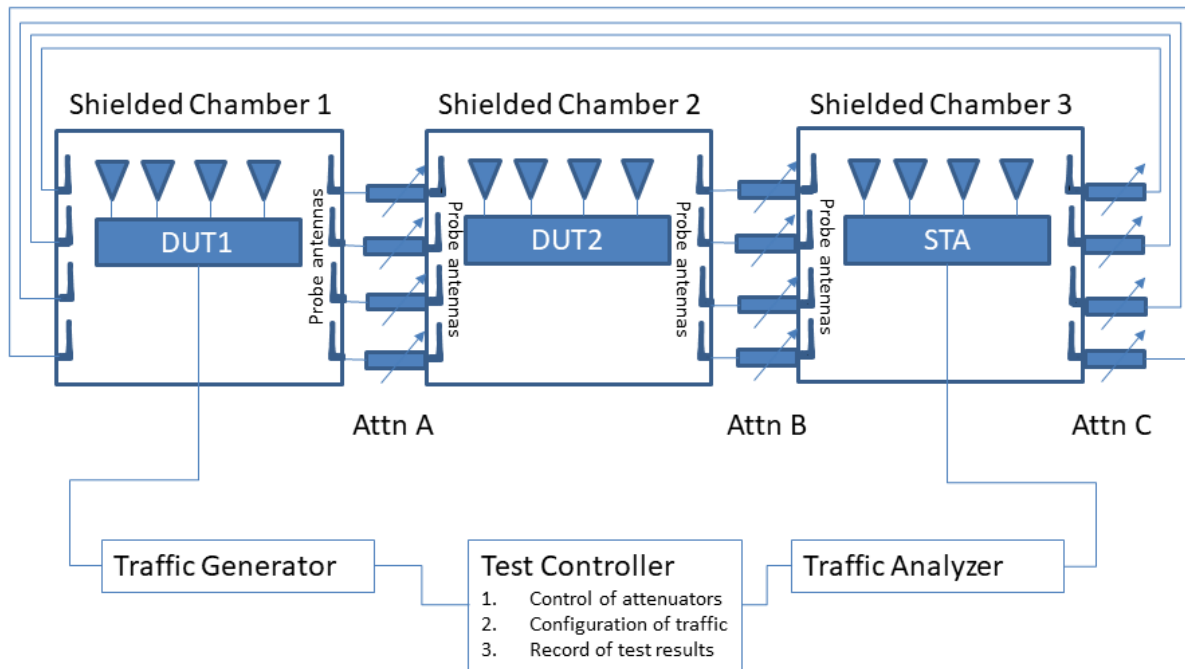


576
577

Figure 3: Multiple Chamber Implementation

578 **5.2.2.3 Wi-Fi Mesh Multiple Chamber Implementation**

579 This test environment is used to create a controlled RF path between 3 separate isolation chambers,
 580 as an expansion of the Multiple Chamber Implementation described above. In this test
 581 environment, the 3 isolation chambers are separated using 3 sets of attenuators (labeled as Attn A,
 582 Attn B, and Attn C). By configuring specific levels of attenuation for each set of attenuators, the
 583 test environment can be used to support testing of a multiple AP scenarios, where the STA might be
 584 connected to the “network” through a Wi-Fi repeater placed in Chamber 2, or the STA could roam
 585 between a wireless network provided by DUT2 and DUT1, as the values of Attn C and Attn B are
 586 changed. Each test case utilizing this test environment SHALL include details of the required Attn
 587 configurations and changes.
 588



589
590
591

Figure 4: Wi-Fi Mesh Multiple Chamber Implementation

592 **5.2.3 STA Requirements**

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

596
597 The STA(s) SHALL have at least the same Wi-Fi physical layer capability (i.e., maximum spatial
598 streams supported and antenna number) as the DUT unless the test case specifies the capability of
599 the STA used in the test. The STA(s) MAY support physical layer capabilities exceeding those of
600 the DUT.

601
602 The STA device(s) used for testing MAY be real products (i.e., a Laptop or Phone) or MAY be
603 dedicated test and measurement equipment that emulates the behavior of standard Wi-Fi station.

604
605 For tests that required multiple STA devices, the devices MAY be multiple discrete devices or the
606 multiple STA devices may be emulated by a single test and measurement device.
607

608
609
610
611
612
613

614 **5.3 Device Under Test (DUT) settings**

615 **5.3.1 DUT Requirements**

616 The DUT SHALL be able to support at least 2 spatial streams ($N_{ss} \geq 2$ as defined in the
617 802.11n/ac/ax specification) for Wi-Fi packet transmission.

618
619 If the DUT supports multiple Wi-Fi channels, the DUT SHALL select channel 6 for 2.4 GHz
620 frequency band and channel 36 for 5 GHz frequency band. The test report SHALL document the
621 channel used in the test plan. If the channel is not supported due to regulatory issue, a neighbor
622 channel SHALL be selected accordingly. The peer STA/STAs register to the DUT to establish the
623 link.

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

625
626 DUT SHALL NOT use any proprietary implementation beyond the scope of Wi-Fi standard [1],
627 e.g., 256QAM modulation for 802.11n, etc.

628

629 **5.3.2 SSID setting**

630 The setting for Service Set Identifier (SSID) SHALL be configured as defined in Table 8. SSID for
631 2.4GHz and 5GHz band SHALL be set up separately. The DUT SHALL be configured to enable
632 only one SSID during all testing, to prevent any performance degradation caused by the broadcast
633 of the additional SSID. For example, some devices may support a “Guest” Wi-Fi network, where
634 this SSID / network needs to be disabled during the testing.

635

636

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
<p>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.</p> <p>Note 2: Defined by test agent.</p>	

637
638

639 **5.3.3 Radio interface settings**

640 Wi-Fi systems are required to conform to various regulatory requirements, based on the region of
 641 the world in which the system is currently operating. One component to these requirements is
 642 typically the definition of the maximum allowed transmit power (Tx Power). Changes to the
 643 transmit power used by the DUT can have an impact on the testing results within this test plan,
 644 where the distance and test channels are defined as absolute attenuation values. In this context, the
 645 transmit power is the power delivered to the antenna by the transmit power amplifier within the
 646 DUT.

647

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

651

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

672

673 Note, the above changes are intended to account for differences within the design and construction
 674 of the DUT, as required by its intended regulatory domain, while not “tuning” the test environment
 675 to each individual DUT, including its antenna and radiation pattern performance, which would
 676 obscure differences between the “real world” performance of individual DUTs.
 677

678 In general, only one operating band/mode is tested at a time, such as 802.11n on 2.4 GHz or
 679 802.11ax on 5 GHz. To ensure the desired band/mode is being tested, the STA SHOULD support a
 680 configuration mechanism to connect only in the desired band. If the STA does not support this
 681 configuration mechanism, only the band/mode being tested SHALL be enabled on the DUT and all
 682 other bands/modes supported by the DUT SHALL be disabled, unless otherwise directed within a
 683 specific test case.

684 **5.3.3.1 802.11n Configuration**

685 All the DUT supporting 802.11n SHALL set the operating frequency band as 2.4 GHz. The default
 686 setting SHALL be configured as defined in Table 9.
 687

688 **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)
<p>Note 1: 100% is corresponding to 20 dBm, this value indicates the aggregated power of all the chains used for communication by air-interface.</p> <p>Note 2: Defined by test agent or automatically selected by the DUT.</p> <p>Note 3: If the DUT does not support control over the enabled standard, the STA SHALL be configured to only enable 802.11n.</p>	

689

690 All of the test cases in this test plan for 802.11n SHALL be conducted in the working frequency of
 691 2.4 GHz. The test plan for 802.11n working in 5 GHz is left for further study.

692 **5.3.3.2 802.11ac Configuration**

693 All the DUT supporting 802.11ac SHALL set the operating frequency band as 5 GHz. The default
 694 setting for work mode SHALL be configured as defined in Table 10.
 695
 696
 697
 698

699
700

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)
<p>Note 1: 100% is corresponding to 23 dBm, this value indicates the aggregated power for all the chains used for communication by air-interface.</p> <p>Note 2: defined by test agent or automatically selected by the DUT.</p> <p>Note 3: If the DUT does not support control over the enabled standard, the STA SHALL be configured to only enable 802.11ac.</p>	

701

702 **5.3.3.3 802.11ax Configuration**

703 All the DUT supporting 802.11ax SHALL set the operating frequency band as either 2.4 GHz or 5
704 GHz. Both bands SHALL be tested. The default setting for work mode SHALL be configured as
705 defined in Table 11.

706
707

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
<p>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.</p> <p>Note 2: Defined by test agent or automatically selected by the DUT.</p> <p>Note 3: Channel 6 SHALL be used for 2.4 GHz testing, Channel 36 SHALL be used for 5 GHz testing.</p>	

708

709
710

711 **6 Performance Tests**

712 Chapter 6 includes a set of test cases for verification of Wi-Fi performance. Test cases are categorized
713 into 5 sets (RF capability, Baseline performance, Coverage, Multiple STAs performance, and
714 Stability/Robustness).
715

716 **6.1 RF capability**

717 **6.1.1 Receiver Sensitivity Test**

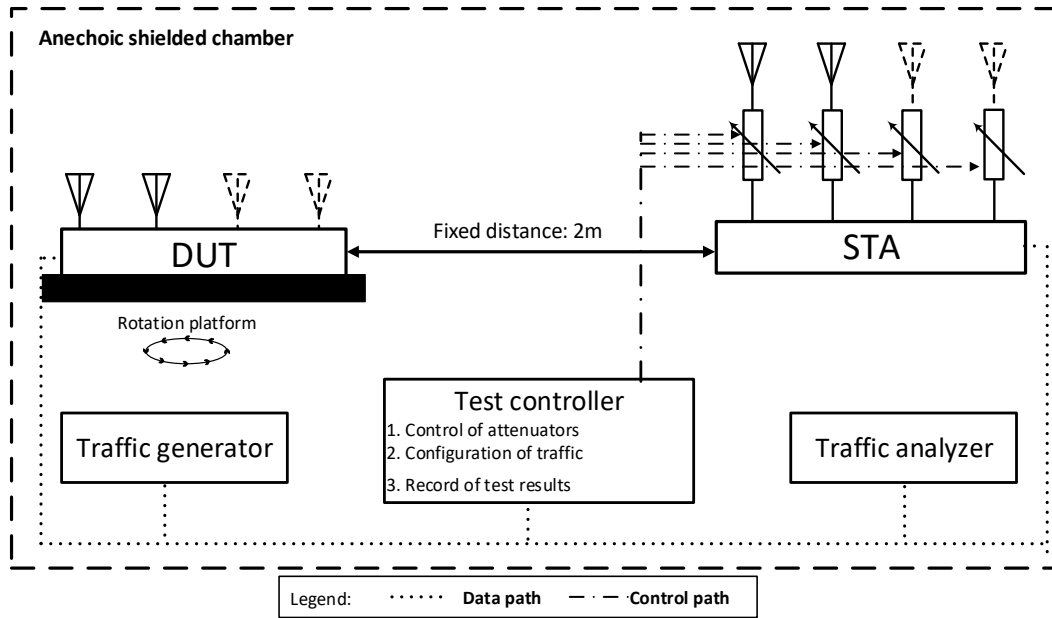
718 **6.1.1.1 Introduction**

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

728
729 This test SHALL be OPTIONAL for the test plan.
730

731 **6.1.1.2 Setup**

- 732 1. The test setup (shown in Figure 5) SHALL utilize a shielded chamber (see section 5.2.1 and 5.2.2).
- 733 2. A Traffic Generator/Analyzer is connected to the station and DUT, capable of sending and
734 receiving Ethernet frames in order to measure packet error rate. A UDP link SHALL be established
735 between DUT and STA and traffic rate SHALL be set to 65% of the theoretical maximum
736 throughput rate for each Modulation and Coding Scheme (MCS). The direction of data packet is
737 from STA to DUT.
- 738 3. A controllable attenuator is added to each RF path between the STA and DUT. The attenuator
739 SHALL support the attenuation values between 0 dB and 60 dB, in 1 dB steps.
- 740 4. The STA SHALL use omnidirectional antenna for packet transmission.
- 741 5. A rotation platform is used to rotate the DUT for angle-based data collection.
742



743
744

Figure 5: Test Setup for Receiver Sensitivity

745 **6.1.1.3 DUT Configuration**

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

748
749

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 (N _{ss} =1) only.	

750
751
752

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

753 **6.1.1.4 Procedure**

- 754 1. Set the rotation angle to 0 degree.
755 2. Configure the STA to use the MCS rate for the first test index from Table 13, Table 14, Table 15,
756 or Table 16 applicable to the test configuration from Table 12.
757 3. Configure the Traffic Generator to use the test data rate from Table 13, Table 14, Table 15, or
758 Table 16 for the configured MCS rate.
759 4. Allow STA to associate with the DUT.
760 5. Configure the attenuator(s) to 0 dB.
761 6. Enable packet generation from the STA to the DUT for 20 seconds.

- 762 7. Record packet error rate (PER).
- 763 8. Increase the attenuator by 1 dB and repeat steps 6-8 until the PER is greater than 10%. Record
- 764 the final attenuation value as the approximate receiver sensitivity.
- 765 9. Increase the rotation angle by 45 degrees. Repeat Step 5 through 8 until the DUT has been
- 766 rotated by 360 degrees. Calculate the average receiver sensitivity.
- 767 10. Repeat steps 1 through 9 for each test index from Table 13, Table 14, Table 15, or Table 16
- 768 applicable to each test configuration from Table 12.
- 769 11. Repeat steps 1 through 10 for each test configuration in Table 12 supported by the DUT.
- 770
- 771

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.

772
773

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.

774
775

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.

776
777

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.				

778

779 **6.1.1.5 Metrics (Pass/Fail Criteria)**

- 780 1. The measured average (between all rotation points) receiver sensitivity (inserted attenuation) in
 781 the test SHALL be greater than or equal to the required receiver sensitivity, as shown in Table 17
 782 and Table 18.
 783
 784

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

785

786

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

787

788

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

789

790

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

791

792 **6.2 Baseline performance**

793 **6.2.1 Maximum Connection Test**

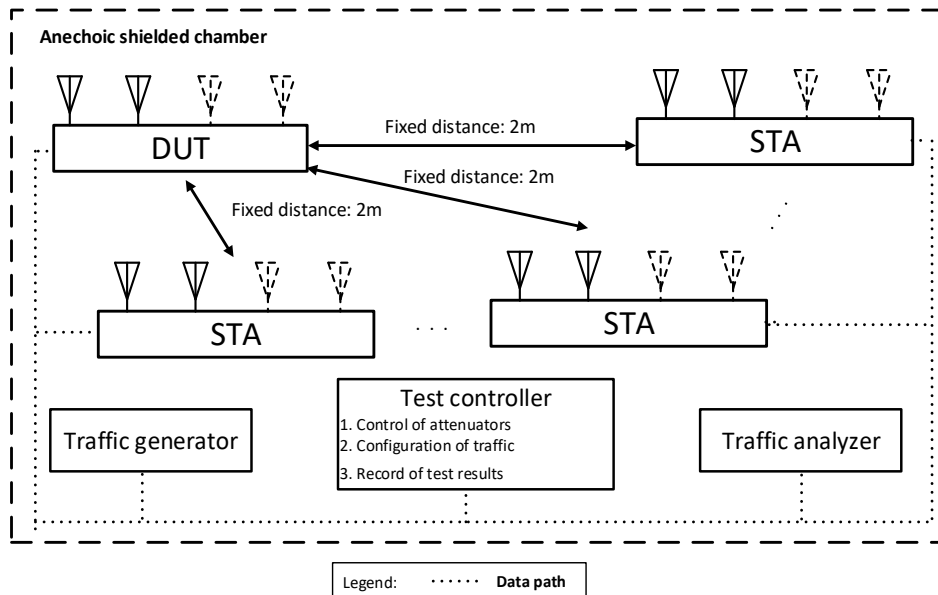
794 **6.2.1.1 Introduction**

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

797
 798 This test SHALL be MANDATORY for the test plan.
 799

800 **6.2.1.2 Setup**

- 801 1. The test setup (shown in Figure 6) SHALL be located in anechoic shielded chamber (see section
 802 5.2.1 and 5.2.2).
 803 2. A Traffic Generator/Analyzer, sending the Ethernet packets, connects to the LAN interface (e.g.,
 804 GE port) of the DUT.
 805 3. The peer STAs is put at a distance of 2 meters to the DUT (For 2.4 GHz band, 2 meters free space
 806 of wireless channel leads to 46 dB attenuation).
 807 4. 32 STAs are prepared and associated to DUT during the test.
 808 5. UDP connection SHALL be used for Ethernet packet transmission in the test.
 809



810
 811 **Figure 6: Test setup of Maximum Connection Test**
 812

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

815 **6.2.1.3 DUT Configuration**

816 The test SHALL run under the following configuration:

- 817 1. The DUT works in different modes if applicable:

- 818 a) 802.11n
- 819 b) 802.11ac
- 820 c) 802.11ax over 2.4 GHz
- 821 d) 802.11ax over 5 GHz

822 **6.2.1.4 Procedures**

- 823 1. Configure the operating mode of the DUT to the first supported configuration listed above.
- 824 2. Allow the STA to associate with the DUT.
- 825 3. Simultaneously measure the downlink UDP packet loss, using a test time of 120 seconds and
826 a traffic rate of 2 Mbps for 802.11n, 8 Mbps for 802.11ac, 3 Mbps for 802.11ax over 2.4
827 GHz, or 10 Mbps for 802.11ax over 5 GHz, through each STA. Record the number of
828 packets transmitted and received to calculate the packet error rate.
- 829 4. Simultaneously measure the uplink UDP packet loss, using a test time of 120 seconds and a
830 traffic rate of 2 Mbps for 802.11n or 8 Mbps for 802.11ac, 3 Mbps for 802.11ax over 2.4
831 GHz, or 10 Mbps for 802.11ax over 5 GHz, through each STA. Record the number of
832 packets transmitted and received to calculate the packet error rate.
- 833 5. Repeat steps 2 through 4 for each additional configuration / operating mode supported by
834 the DUT.
835

836 **6.2.1.5 Metrics (Pass/Fail Criteria)**

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

- 839 1. For each of the test configuration, Packet Error Rate (PER) for each STA SHALL achieve less
840 than 1 %.
- 841 2. For each of the test configuration, the overall throughput of all connected STA SHALL achieve:
842 a) For 32 connected STA (802.11n), both downlink and uplink summed throughput SHALL be
843 not less than 64 Mbps * 99%.
- 844 b) For 32 connected STA (802.11ac), both downlink and uplink summed throughput SHALL
845 be not less than 256 Mbps * 99%.
- 846 c) For 32 connected STA (802.11ax over 2.4 GHz), both downlink and uplink summed
847 throughput SHALL be not less than 96 Mbps * 99%.
- 848 d) For 32 connected STA (802.11ax over 2.4 GHz), both downlink and uplink summed
849 throughput SHALL be not less than 320 Mbps * 99%.

850

851 **6.2.2 Maximum Throughput Test**

852 **6.2.2.1 Introduction**

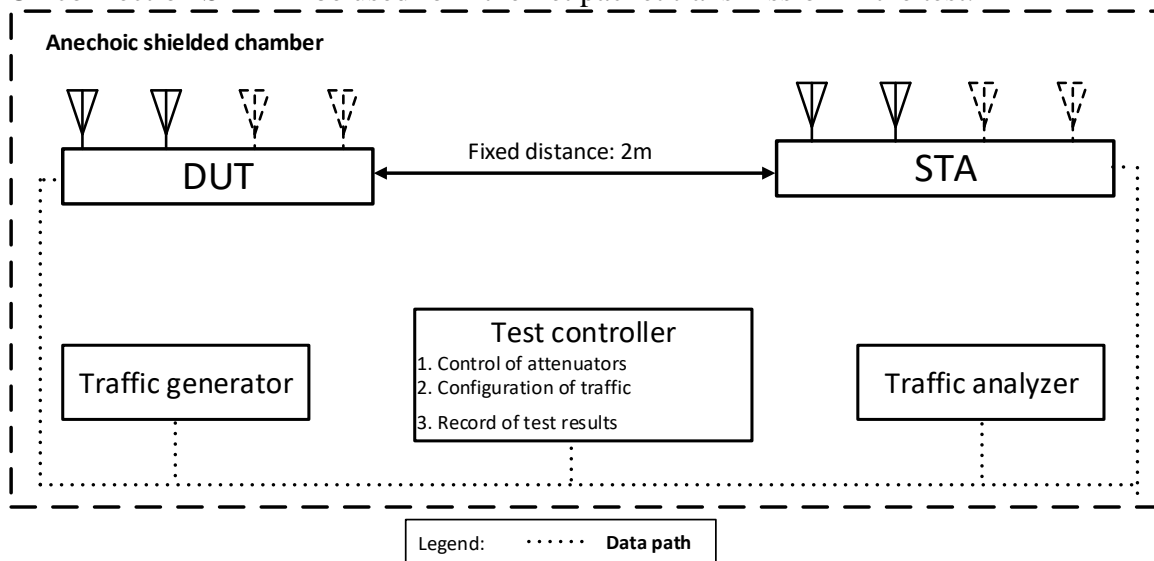
853 Maximum throughput test intends to measure the maximum throughput performance of the DUT. The
854 test is conducted with connection by air interface in short distance (by considering the actual
855 utilization of Wi-Fi).

856

857 This test SHALL be MANDATORY for the test plan.
 858

859 **6.2.2.2 Setup**

- 860 1. The test setup (shown in Figure 7) SHALL be located in the anechoic shielded chamber (see
- 861 section 5.2.1 and 5.2.2).
- 862 2. A Traffic Generator/Analyzer, sending the Ethernet packets, connects to the LAN interface (e.g.,
- 863 GE port) of the DUT. The peer STA is put at a distance of 2 meters to the DUT (For 2.4 GHz
- 864 band, 2 meter free space of wireless channel leads to 46 dB attenuation).
- 865 3. TCP connection SHALL be used for Ethernet packet transmission in the test.



866
 867 **Figure 7: Test setup of Maximum Throughput Test**

868 **6.2.2.3 DUT configuration**

869 The test SHALL run under the following configuration:

- 870 1. The DUT works in different modes:
 - 871 a) 802.11n
 - 872 b) 802.11ac
 - 873 c) 802.11ax over 2.4 GHz
 - 874 d) 802.11ax over 5 GHz

875
 876 The test case SHALL be conducted on all the applicable modes of the DUT.
 877

878 **6.2.2.4 Procedures**

- 879 1. Configure the working mode of DUT to 802.11n with default configuration.
- 880 2. Establish the LAN connection and allow STA to associate with the DUT.
- 881 3. Measure the downlink TCP throughput to the STA, using a test time of 120 seconds.
- 882 4. Measure the uplink TCP throughput to the STA, using a test time of 120 seconds.
- 883 5. Set the working mode of DUT to 802.11ac, and repeat steps 3-4 for bandwidth 80MHz.

- 884 6. Set the working mode of DUT to 802.11ax over 2.4 GHz, and repeat steps 3-4.
- 885 7. Set the working mode of DUT to 802.11ax over 5 GHz, and repeat steps 3-4.

886
887
888
889
890

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.

891 **6.2.2.5 Metrics (Pass/Fail Criteria)**

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

- 894 1. The measured average throughput SHALL meet the performance requirement of Table 21
895 according to the GI used in the test.

896
897

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

898
899
900

901 **6.2.3 Airtime Fairness Test**

902 **6.2.3.1 Introduction**

903 Wi-Fi signal transmission can be seen as a multicast process since the STAs involved share the
904 transmission medium. Air interface becomes a rare resource when dense connections or high
905 throughput requests exist. Channel condition determines the MCS selection, therefore affecting the
906 data throughput. In general, long distance to travel or obstacle penetration leads to larger attenuation,
907 which makes the data rate in a low level. Occupying excessive air time of STA with small MCS will

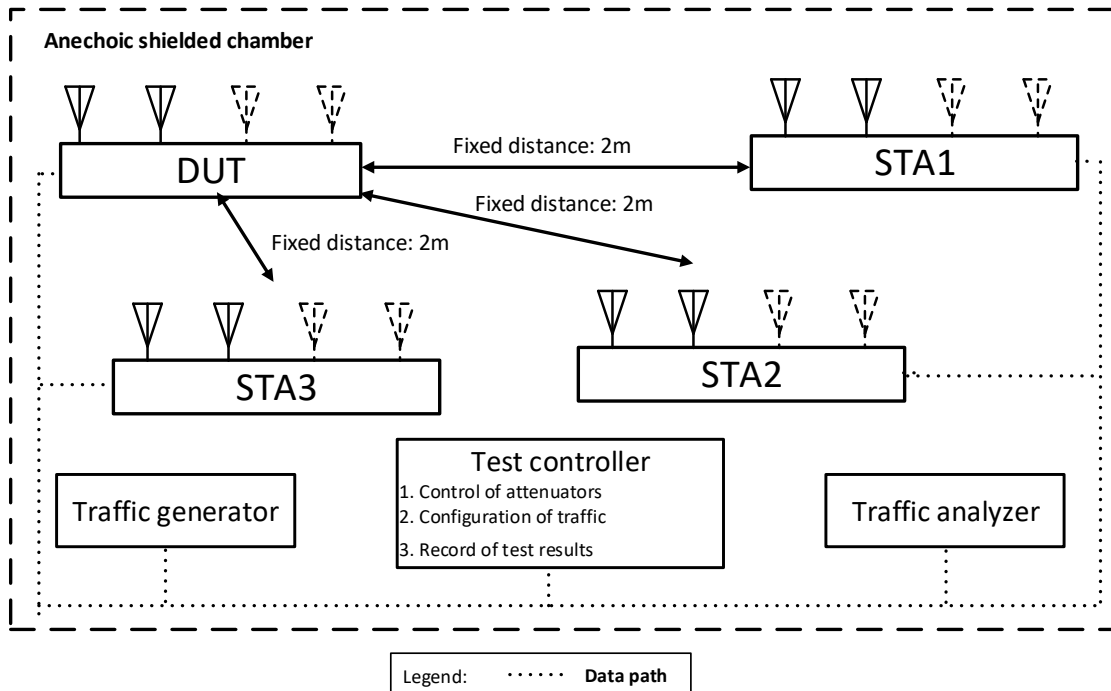
908 be unfair to the STAs with large MCS (here, assuming the QoS requirement is similar) when the air
 909 resources have already run out.

910
 911 Airtime Fairness Test intends to verify the capability of Wi-Fi device to guarantee the fairness of
 912 airtime usage.

913
 914 This test SHALL be MANDATORY for the test plan.
 915

916 **6.2.3.2 Setup**

- 917 1. The test setup (shown in Figure 8) SHALL locate in the anechoic shielded chamber (see section
 918 5.2.1 and 5.2.2).
- 919 2. Three peer STAs are used in the test. STA1 and STA2 are 802.11n/ac devices with the same
 920 number of spatial streams supported by the DUT in both 2.4 and 5GHz bands. STA3 is a legacy
 921 802.11a/b/g, 802.11n Nss = 1, or 802.11ac Nss = 1 devices, depending on the operating mode
 922 under test. All STAs are located in the distance of 2 meter to the DUT (For 2.4 GHz band, 2
 923 meter free space of wireless channel leads to 46 dB attenuation).
- 924 3. DUT is set to 2.4 GHz operating frequency band with default configuration in the beginning of
 925 the test.
- 926 4. A Traffic Generator/Analyzer, sending the Ethernet packet to each peer STA, connects to the
 927 LAN interface (e.g., GE port) of the DUT.
- 928 5. The TCP connection SHALL be used for Ethernet packet transmission in the test.
 929



930
 931 **Figure 8: Test setup of Airtime Fairness Test**
 932

933 6.2.3.3 DUT Configuration

934 The test SHALL run under the default configuration.

935

936 6.2.3.4 Procedures

- 937 1. Establish the setup using default configuration for the 802.11n operating mode.
- 938 2. Associate STA1 and STA2 with DUT. Establish the LAN connection and wait for 10 seconds.
- 939 3. Measure the downlink TCP throughput to each STA1 and STA2, using a test time of 120 seconds.
- 940 Record this as STA1_throughput_1 and STA2_throughput_1.
- 941 4. Move STA2 to a medium distance to the DUT (equivalent to 38 dB@2.4GHz and 25 dB @5GHz
- 942 attenuation between DUT and STA2). Wait for 10 seconds.
- 943 5. Measure the downlink TCP throughput to STA 1 and STA2, using a test time of 120 seconds.
- 944 Record this as STA1_throughput_2 and STA2_throughput_2.
- 945 6. Disassociate STA2 with the DUT. Replace STA 2 by STA 3 and remove the attenuation. STA3
- 946 is configured to support only a 2.4 GHz connection. Establish the Wi-Fi connection between
- 947 STA3 and DUT and wait for 10 seconds.
- 948 7. Measure the downlink TCP throughput to STA 1 and STA3, using a test time of 120 seconds.
- 949 Record this as STA1_throughput_3 and STA3_throughput_3.
- 950 8. Replace STA3 with a STA that uses only 802.11a. Set the DUT to operating mode of 802.11ac.
- 951 Repeat steps 2 to 7.
- 952 9. Replace STA3 with a STA that uses only 802.11n. Set the DUT to operating mode of 802.11ax
- 953 2.4 GHz. Repeat steps 2 to 7.
- 954 10. Replace STA3 with a STA that uses only 802.11ac. Set the DUT to operating mode 802.11ax 5
- 955 GHz. Repeat steps 2 to 7.
- 956

957 6.2.3.5 Metrics (Pass/Fail Criteria)

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

959 following:

960 a) The throughput variation of DUT SHALL meet:

961

962 For the test in 802.11n 2.4 GHz frequency band:

- 963 1) STA1_throughput_1 SHALL be within $(1\pm 5\%)*\text{Mean}(\text{STA2_throughput_1},$
- 964 STA1_throughput_1) .
- 965 2) STA2_throughput_1 SHALL be within $(1\pm 5\%)*\text{Mean}(\text{STA2_throughput_1},$
- 966 STA1_throughput_1) .
- 967 3) STA1_throughput_2 SHALL be within $(1\pm 15\%)*\text{Mean}(\text{STA2_throughput_1},$
- 968 STA1_throughput_1) .
- 969 4) STA1_throughput_3 SHALL be within $(1\pm 15\%)*\text{Mean}(\text{STA2_throughput_1},$
- 970 STA1_throughput_1).

971

972 For the test in 802.11ac 5 GHz frequency band:

- 973 1) STA1_throughput_1 SHALL be within $(1\pm 10\%)*\text{Mean}(\text{STA2_throughput_1},$
- 974 STA1_throughput_1).

- 975 2) STA2_throughput_1 SHALL be within $(1\pm 10\%)*\text{Mean}(\text{STA2_throughput_1},$
976 STA1_throughput_1).
- 977 3) STA1_throughput_2 SHALL be within $(1\pm 35\%)*\text{Mean}(\text{STA2_throughput_1},$
978 STA1_throughput_1).
- 979 4) STA1_throughput_3 SHALL be within $(1\pm 35\%)*\text{Mean}(\text{STA2_throughput_1},$
980 STA1_throughput_1).

981

982 For the test in 802.11ax 2.4 GHz frequency band:

- 983 1) STA1_throughput_1 SHALL be within $(1\pm 5\%)*\text{Mean}(\text{STA2_throughput_1},$
984 STA1_throughput_1) .
- 985 2) STA2_throughput_1 SHALL be within $(1\pm 5\%)*\text{Mean}(\text{STA2_throughput_1},$
986 STA1_throughput_1) .
- 987 3) STA1_throughput_2 SHALL be within $(1\pm 15\%)*\text{Mean}(\text{STA2_throughput_1},$
988 STA1_throughput_1) .
- 989 4) STA1_throughput_3 SHALL be within $(1\pm 15\%)*\text{Mean}(\text{STA2_throughput_1},$
990 STA1_throughput_1).

991

992 For the test in 802.11ax 5 GHz frequency band:

- 993 1) STA1_throughput_1 SHALL be within $(1\pm 20\%)*\text{Mean}(\text{STA2_throughput_1},$
994 STA1_throughput_1).
- 995 2) STA2_throughput_1 SHALL be within $(1\pm 20\%)*\text{Mean}(\text{STA2_throughput_1},$
996 STA1_throughput_1).
- 997 3) STA1_throughput_2 SHALL be within $(1\pm 35\%)*\text{Mean}(\text{STA2_throughput_1},$
998 STA1_throughput_1).
- 999 4) STA1_throughput_3 SHALL be within $(1\pm 35\%)*\text{Mean}(\text{STA2_throughput_1},$
1000 STA1_throughput_1).

1001

1002 b) The throughput of DUT SHALL meet:

1003

1004 For the test in 802.11n 2.4 GHz frequency band with Nss = 2:

- 1005 1) The summation of STA1_throughput_1 and STA2_throughput_1 SHALL be larger than 90
1006 Mbps.
- 1007 2) The summation of STA1_throughput_2 and STA2_throughput_2 SHALL be larger than 80
1008 Mbps.
- 1009 3) The summation of STA1_throughput_3 and STA3_throughput_3 SHALL be larger than 60
1010 Mbps.

1011

1012 For the test in 802.11ac 5 GHz frequency band with Nss = 2:

- 1013 1) The summation of STA1_throughput_1 and STA2_throughput_1 SHALL be larger than 570
1014 Mbps.
- 1015 2) The summation of STA1_throughput_2 and STA2_throughput_2 SHALL be larger than 570
1016 Mbps.
- 1017 3) The summation of STA1_throughput_3 and STA3_throughput_3 SHALL be larger than 265
1018 Mbps.

1019

1020 For the test in 802.11ax 2.4 GHz frequency band with Nss = 2:

- 1021 1) The summation of STA1_throughput_1 and STA2_throughput_1 SHALL be larger than 160
1022 Mbps.
1023 2) The summation of STA1_throughput_2 and STA2_throughput_2 SHALL be larger than 108
1024 Mbps.
1025 3) The summation of STA1_throughput_3 and STA3_throughput_3 SHALL be larger than 100
1026 Mbps.

1027

1028 For the test in 802.11ax 5 GHz frequency band with Nss = 2:

- 1029 1) The summation of STA1_throughput_1 and STA2_throughput_1 SHALL be larger than 610
1030 Mbps.
1031 2) The summation of STA1_throughput_2 and STA2_throughput_2 SHALL be larger than 360
1032 Mbps.
1033 3) The summation of STA1_throughput_3 and STA3_throughput_3 SHALL be larger than 295
1034 Mbps.
1035

1036 6.2.4 Dual-band Throughput Test

1037 6.2.4.1 Introduction

1038 The Dual-band Throughput Test is intended to measure the throughput the DUT can support when
1039 concurrently connected to multiple stations on both the 2.4 and 5 GHz bands, each operating with
1040 two spatial streams. The purpose of these additional test cases is to detect cross band interference
1041 of the DUT's transmitter on the receiver. The weak link is needed to ensure DUT and STA are
1042 transmitting at the highest power and causing the most potential interference when the receiver is
1043 more susceptible to noise (low SNR). Note, each station is connected using either the 2.4 or 5 GHz
1044 band, but not both bands simultaneously. This test requires at least 2 stations, located 2m from the
1045 DUT. The DUT will need to support at least 4 independent radio chains for this test case, two
1046 operating in the 2.4 GHz band and two operating in the 5 GHz band.

1047

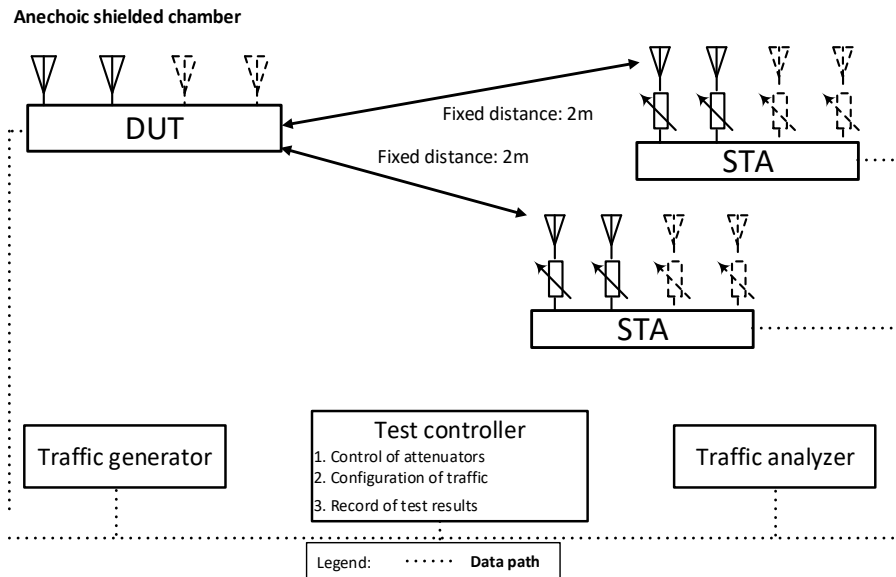
1048 This test SHALL be MANDATORY for the test plan.

1049

1050 6.2.4.2 Setup

- 1051 1. The test setup (shown in Figure 9) SHALL be located in the anechoic shielded chamber (see
1052 section 5.2.1 and 5.2.2), using 2 stations.
1053 2. The peer STAs are put at a distance of 2 meters to the DUT. For 2.4 GHz band, 2 meters
1054 free space of wireless channel leads to 46 dB attenuation.
1055 3. Additional attenuation is added in each RF chain of STA to simulate the incremental
1056 distance. Configure the attenuators to an initial value of 10 dB.
1057 4. Configure one station to enable only the 2.4 GHz band, configure the other station to enable
1058 only the 5 GHz band.
1059 5. A Traffic Generator/Analyzer, sending the Ethernet packets, connects to the LAN interface
1060 (e.g., GE port) of the DUT.
1061 6. TCP connections SHALL be used for Ethernet packet transmission in the test.

1062



1063
1064
1065

Figure 9: Test setup Dual-band Throughput Test

1066 **6.2.4.3 DUT configuration**

1067 The test SHALL run under the following configuration:

- 1068 1. The DUT works in different modes:
 - 1069 a. 802.11n and 802.11ac
 - 1070 b. 802.11ax 2.4 GHz and 802.11ax 5 GHz

1071

1072 **6.2.4.4 Procedures**

- 1073 1. Configure the working mode of DUT to enable both 802.11n and 802.11ac with the default
- 1074 configuration (see section 5.3).
- 1075 2. Establish the LAN connection and allow all STA to associate with the DUT.
- 1076 3. Simultaneously measure the downlink TCP throughput to all STA, using a test time of 120
- 1077 seconds.
- 1078 4. Simultaneously measure the uplink TCP throughput to all STA, using a test time of 120
- 1079 seconds
- 1080 5. Simultaneously measure the downlink TCP throughput to the 802.11n STA and the uplink
- 1081 TCP throughput to the 802.11ac STA.
- 1082 6. Simultaneously measure the uplink TCP throughput to the 802.11n STA and the downlink
- 1083 TCP throughput to the 802.11ac STA.
- 1084 7. Repeat steps 1 through 6 with the attenuators set to 32 dB for 2.4 GHz STA and 25 dB for 5
- 1085 GHz STA.
- 1086 8. Repeat steps 1 through 6 with the attenuators set to 42 dB for 2.4 GHz STA and 35 dB for 5
- 1087 GHz STA.
- 1088 9. Repeat steps 1 through 8 for each configuration listed above in 6.2.4.3.
- 1089

1090 **Note:** The test result MAY be slightly affected by the capability of Peer STA. The test can be
 1091 conducted with different peer STAs with chipsets from different vendors. The calculated average
 1092 throughput then can be averaged again in the dimension of chipset.
 1093 **Note:** The simultaneous measurements imply 2 TCP measurement streams connecting two IP hosts,
 1094 each located at one STA.
 1095

1096 **6.2.4.5 Metrics (Pass/Fail Criteria)**

1097 In order to pass the test case, the recorded results SHALL meet the Pass/Fail Criteria, described as
 1098 following:

- 1099 1. For each attenuation value, at least 7 of the 8 measured average throughputs SHALL meet
 1100 the performance requirements of Table 22.
 1101
 1102

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
<p>Notes:</p> <ol style="list-style-type: none"> Note, the requirements per each row apply to measurements made simultaneously (at the same time) for the described test point. If the DUT can only support the long guard interval (GI = 800 ns), the performance requirements above SHALL be reduced by 10%. For 802.11ax, all performance requirements refer to guard interface of GI =800 ns. 						

1103
1104

1105 **6.2.5 Bidirectional Throughput Test**

1106 **6.2.5.1 Introduction**

1107 The Bidirectional Throughput Test measures the uplink and downlink simultaneously achieved
1108 through the DUT and a station.

1109
1110 This test SHALL be MANDATORY for the test plan.

1111 **6.2.5.2 Setup**

- 1112 1. The test setup (shown in Figure 7) SHALL be located in the anechoic shielded chamber
1113 (see section 5.2.1 and 5.2.2). The peer STA is put at a distance of 2 meters to the DUT
1114 (For 2.4 GHz band, 2 meters free space of wireless channel leads to 46 dB attenuation).
1115 2. Configure the DUT and STA to use the 2.4 GHz band, per the settings in Section 5.3.
1116 3. Configure the attenuator to 10 dB.

- 1117 4. A Traffic Generator/Analyzer, sending the Ethernet packets, connects to the LAN
1118 interface (e.g., GE port) of the DUT. TCP connections SHALL be used for Ethernet
1119 packet transmission in the test.
1120

1121 6.2.5.3 DUT configuration

1122 The test SHALL run under the following configuration:

- 1123 1) The DUT works in different modes:
1124 a) 802.11n
1125 b) 802.11ac
1126 c) 802.11ax over 2.4 GHz
1127 d) 802.11ax over 5 GHz

1128 6.2.5.4 Procedures

- 1129 1. Establish the LAN connection and allow the STA to associate with the DUT.
1130 2. Measure the achievable downlink TCP throughput, using a test time of 120 seconds. Record
1131 this value as Throughput_Max_DL.
1132 3. Measure the achievable uplink TCP throughput, using a test time of 120 seconds. Record
1133 this value as Throughput_Max_UL.
1134 4. Configure bidirectional UDP traffic streams to use an downlink data rate set to 45% of
1135 Throughput_Max_DL and an uplink data rate of 45% of Throughput_Max_UL. Record
1136 these values as Throughput_DL and Throughput_UL respectively.
1137 5. Simultaneously run the bidirectional UDP traffic for 120 seconds, recording the number of
1138 packets transmitted, received, and dropped in each direction.
1139 6. Calculate the PACKET_LOSS_RATIO_DL and PACKET_LOSS_RATIO_UL as the
1140 number of lost packets divided by the total number of packets transmitted.
1141 7. Repeat steps 1 through 6 for attenuator settings 21 dB and 42 dB for 2.4 GHz DUT
1142 configurations or 21 dB and 35 dB for 5 GHz DUT configurations.
1143 8. Repeat steps 1 through 7 for each configuration listed above in Section 6.2.5.3.
1144

1145 **Note:** The test result MAY be slightly affected by the capability of Peer STA. The test
1146 can be conducted with different peer STAs with chipsets from different vendors. The
1147 calculated average throughput then can be averaged again in the dimension of chipset.
1148

1149 6.2.5.5 Metrics (Pass/Fail Criteria)

1150 In order to pass the test case, the recorded results SHALL meet the Pass/Fail Criteria, described as
1151 following:

- 1152 1. Each measured PACKET_LOSS_RATIO_DL and PACKET_LOSS_RATIO_UL SHALL
1153 be less than or equal to 1E-4.

1155 6.3 Coverage

1156 **6.3.1 Range Versus Rate Test**

1157 **6.3.1.1 Introduction**

1158 Range versus rate test intends to measure the baseband and RF chain performance of Wi-Fi device.
1159 The attenuation of signals due to increasing range is achieved by using attenuator(s) in the RF path
1160 between the AP and STA.

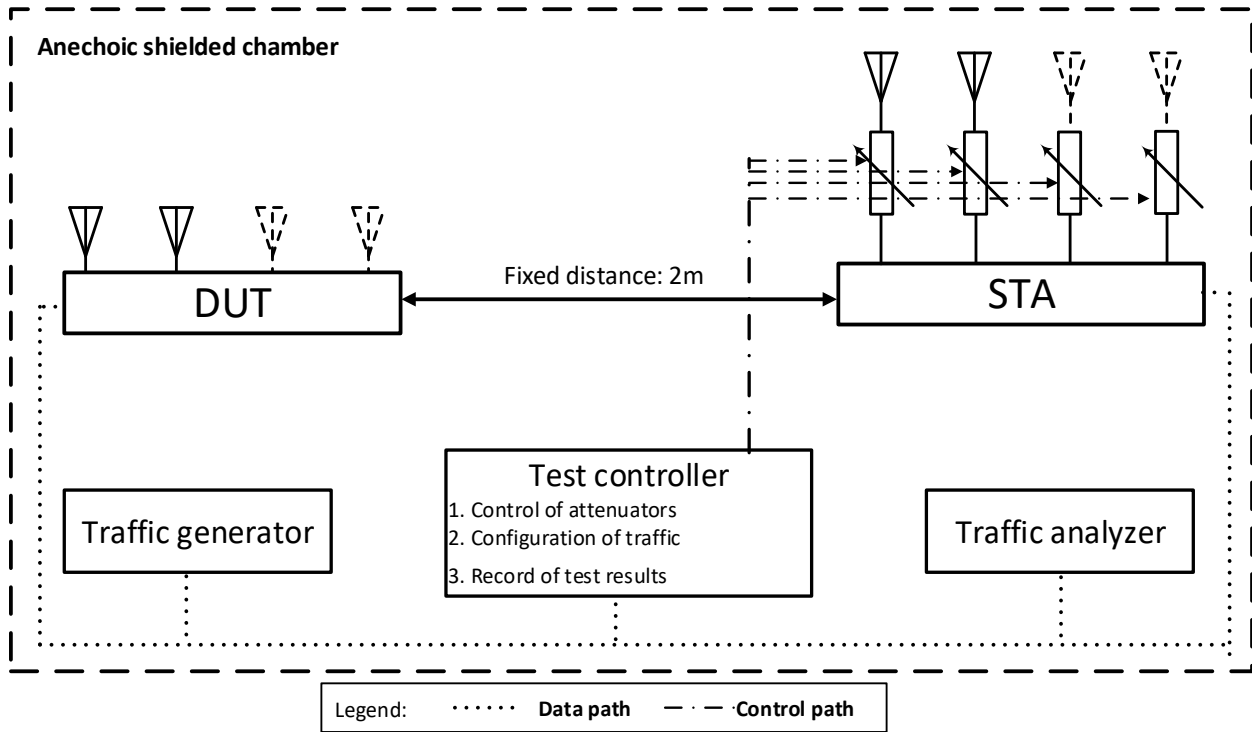
1161
1162 This test SHALL be MANDATORY for the test plan.
1163

1164 **6.3.1.2 Setup**

- 1165 1. The test setup (shown in Figure 10) SHALL locate in the anechoic shielded chamber (see
1166 section 5.2.1 and 5.2.2).
- 1167 2. A Traffic Generator/Analyzer, sending the Ethernet packets, connects to the LAN interface
1168 (e.g., GE port) of the DUT. The peer STA is located 2 meters to the DUT (46dB attenuation for
1169 2.4 GHz, 53 dB attenuation for 5.2 GHz).
- 1170 3. Additional attenuation is added to simulate the incremental distance. The specific attenuation
1171 values used for testing are defined in 6.3.1.3.
- 1172 4. The host SHALL send the Ethernet packet at the maximum rate which the DUT can achieve
1173 theoretically.
- 1174 5. TCP connection SHALL be used for Ethernet packet transmission in the test.
1175

1176 **Note 1:** The attenuators need to be capable of providing attenuation steps between 0dB ~
1177 63dB for the selected operating frequency band.

1178 **Note 2:** A channel simulator, which emulates a specific real environment, MAY be used to
1179 replace the simple attenuators for more comprehensive test.
1180



1181
1182

Figure 10: Test setup of Range Versus Rate Test

1183 **6.3.1.3 DUT Configuration**

1184 The test SHALL run under the following configuration:

- 1185 1. General configuration for DUT/STA working mode, bandwidth and number of RF chains:
1186
1187

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

1188
1189
1190
1191
1192

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

1193

1194 **6.3.1.4 Procedures**

- 1195 1. Configure the attenuator with 0 dB attenuation. Configure the working mode of DUT to 802.11n
 1196 and operating frequency band to 2.4 GHz with default configuration.
 1197 2. Establish the LAN connection and allow STA to associate with the DUT.
 1198 3. Measure the downlink TCP throughput to the STA, using a test time of 120 seconds.
 1199 4. Measure the uplink TCP throughput to the DUT, using a test time of 120 seconds.
 1200 5. Change the attenuation for STA RF chain according to 6.3.1.3 until the attenuation reaches to 63
 1201 dB. Repeat step 2-4.
 1202 6. Configure the attenuator with 0 dB attenuation. Set the working mode of DUT to 802.11ac with
 1203 80MHz bandwidth. Repeat step 2-4 for all attenuation values in section 6.3.1.3.
 1204 7. Configure the attenuator with 0 dB attenuation. Set the working mode of DUT to 802.11ax over
 1205 2.4 GHz with 20MHz bandwidth. Repeat step 2-4 for all attenuation values in section 6.3.1.3.
 1206 8. Configure the attenuator with 0 dB attenuation. Set the working mode of DUT to 802.11ax over
 1207 5 GHz with 80MHz bandwidth. Repeat step 2-4 for all attenuation values in section 6.3.1.3.

1208 **Note:** The test result MAY be slightly affected by the capability of Peer STA. The test MAY be conducted with
 1209 different peer STAs with chipsets from different vendors. The calculated average throughput then is averaged
 1210 again in the dimension of chipset.
 1211
 1212

1213 **6.3.1.5 Metrics (Pass/Fail Criteria)**

1214 In order to pass the test case, the recorded results SHALL meet the Pass/Fail Criteria, described as
 1215 following:

1216 The measured average throughput SHALL meet the performance requirement of Table 25. For each
 1217 operating mode (i.e. 802.11n or 802.11ax over 5 GHz), no more than 2 test points SHALL fall
 1218 below the throughput requirement..
 1219
 1220

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

1221
1222

1223 **6.3.2 Spatial consistency test**

1224 **6.3.2.1 Introduction**

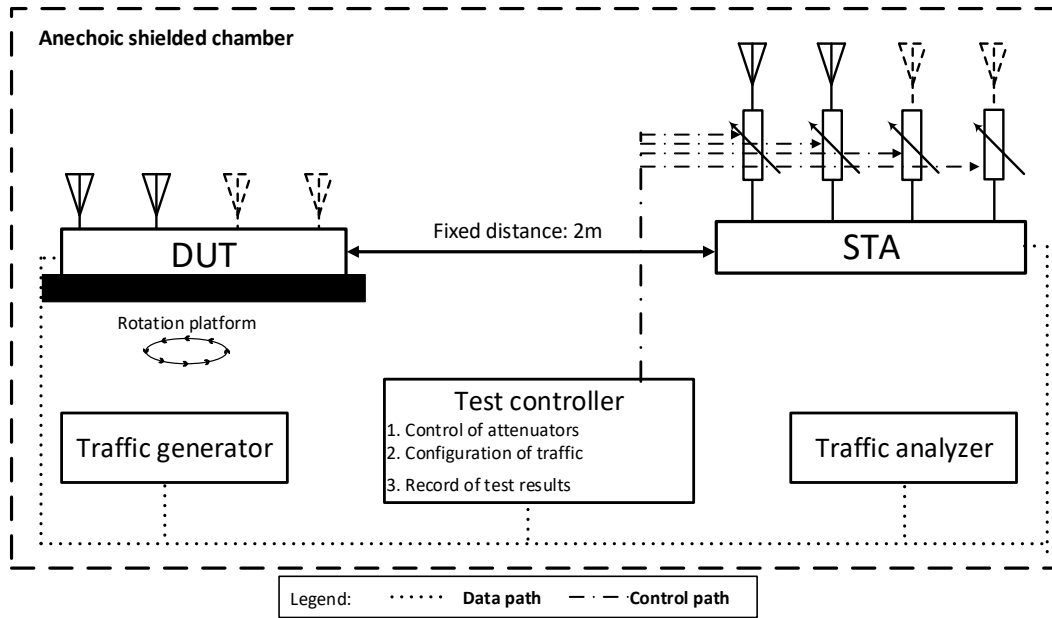
1225 Spatial consistency test intends to verify the Wi-Fi signal consistency in spatial domain.

1226
1227 This test SHALL be MANDATORY for the test plan.

1228

1229 **6.3.2.2 Setup**

- 1230 1. The test setup (shown in Figure 11) SHALL locate in the anechoic shielded chamber (see section
1231 5.2.1 and 5.2.2), DUT and peer STA is in a distance of 2 meters. DUT is fixed in a two-
1232 dimensional rotation platform.
- 1233 2. A Traffic Generator/Analyzer, sending the Ethernet packet, connects to the LAN interface (e.g.,
1234 GE port) of the DUT. The Peer STA receives the Wi-Fi packet from the DUT through air
1235 interface.
- 1236 3. Additional attenuation is added to simulate the incremental distance. The concrete values are
1237 defined in 6.3.2.3.
- 1238 4. TCP connection SHALL be used for Ethernet packet transmission in the test.
- 1239



1240
1241

Figure 11: Test setup of Spatial Consistency Test

1242 **6.3.2.3 DUT Configuration**

1243 The test SHALL run under the following configuration if applicable:

- 1244 1. General configuration for DUT/STA working mode, bandwidth and number of RF chains:

1245
1246

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

1247
1248
1249
1250
1251
1252

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.

1253 **6.3.2.4 Procedures**

- 1254 1. Configure the working mode of DUT to 802.11n, operating frequency band to 2.4 GHz with
1255 default configuration.
- 1256 2. Establish the LAN connection and allow STA to associate with to the DUT.
- 1257 3. Measure the downlink TCP throughput to the STA, using a test time of 60 seconds. Wait for 10
1258 seconds. Measure the uplink TCP throughput to the STA, using a test time of 60 seconds.

- 1259 4. Rotate the DUT platform by 30° and repeat Step 3 until the platform has been rotated by 360°.
- 1260 5. Increase the attenuation for each RF chain according to 6.3.2.3 and reset the position of DUT
- 1261 platform to 0°, until all the attenuation values have been tested. Repeat Step 2-5.
- 1262 6. Set the working mode of DUT to 802.11ac with a bandwidth of 80 MHz and operating frequency
- 1263 to 5 GHz, reset the position of DUT platform to 0°. Repeat Step 2-5.
- 1264 7. Set the working mode of DUT to 802.11ax over 2.4 GHz with a bandwidth of 20 MHz and reset
- 1265 the position of DUT platform to 0°. Repeat Step 2-5.
- 1266 8. Set the working mode of DUT to 802.11ax over 5 GHz with a bandwidth of 80 MHz and reset
- 1267 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.

1273 **6.3.2.5 Metrics (Pass/Fail Criteria)**

1274 In order to pass the test case, the recorded results SHALL meet the Pass/Fail Criteria, described as

1275 following:

- 1276 a) The average throughput measured at each angle SHALL meet the requirements in Table 27 for
- 1277 at least 10 of the 12 measurement points (rotation angle) for each operating mode and attenuator
- 1278 setting.

1280 **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

- 1281
- 1282
- 1283
- 1284 b) The maximum variation during rotation SHALL satisfy the requirements in Table 28:
- 1285

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.

1288

1289 **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%

1290
1291

1292 **6.3.3 802.11ax Peak Performance Test**

1293 **6.3.3.1 Introduction**

1294 This test case examines the maximum performance expected from a DUT supporting 802.11ax with
1295 the following additional capabilities beyond the default configuration: 4 spatial streams, 160 MHz
1296 Channels.

1297
1298 This test SHALL be MANDATORY for the test plan.
1299

1300 **6.3.3.2 Setup**

- 1301 1. The test setup (shown in Figure 6) SHALL be located in the anechoic shielded chamber (see
1302 section 5.2.1 and 5.2.2).
- 1303 2. The peer STA is put at a distance of 2 meters to the DUT (For 2.4 GHz band, 2 meter free space
1304 of wireless channel leads to 46 dB attenuation).
- 1305 3. A Traffic Generator/Analyzer, sending the Ethernet packets, connects to the LAN interface
1306 (e.g., GE port) of the DUT.
- 1307 4. TCP connection(s) SHALL be used to measure the throughput between the STA and DUT.

1308 **6.3.3.3 DUT Configuration**

1309 The STA and DUT SHALL be configured for the following operating modes during this testing.
1310

1311 **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.	

1312

1313 **6.3.3.4 Procedures**

- 1314 1. Configure the operating mode of the DUT and STA to the first configuration in Table 29.
 1315 2. Establish the LAN connection and allow STA to associate with the DUT.
 1316 3. Measure the downlink TCP throughput to the STA, using a test time of 120 seconds.
 1317 4. Measure the uplink TCP throughput to the STA, using a test time of 120 seconds.
 1318 5. Repeat steps 1 through 4 for each additional configuration in Table 29 supported by the DUT.

1319 **6.3.3.5 Metrics (Pass/Fail Criteria)**

- 1320 1. For each configuration, the measured throughput MUST be equal to, or greater than the
 1321 values listed in the table below.
 1322 a. If the DUT includes only 1 Gbps Ethernet connections, the requirement for any
 1323 metric exceeding 1 Gbps, such as Config 2, SHALL become 950 Mbps.
 1324
 1325

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.		

1326

1333 **6.4 Multiple STAs Performance**

1334 **6.4.1 Multiple STAs Performance Test**

1335 **6.4.1.1 Introduction**

1336 Multiple STAs performance test intends to measure the performance of Wi-Fi device connected with
 1337 multiple STAs simultaneously. To simulate a circumstance of real environment, various levels of
 1338 signals reflecting various distance between Wi-Fi device and STA are considered in the test.

1339
 1340 This test SHALL be MANDATORY for the test plan.
 1341

1342 **6.4.1.2 Setup**

1343 The same test setup shown in Figure 10 SHALL be used. Note the STA in Figure 10 is duplicated by
 1344 9 times in this test.

- 1345 1. Total 9 STAs are engaged in the test. Three STAs are located in a short distance to the DUT.
 1346 Three STAs are located in a medium distance to the DUT. The rest STAs are located in a long
 1347 distance to the DUT. The short/medium/long distance are emulated by adding additional
 1348 attenuation for the signals as follows:
 1349 a) STA in short distance: 10 dB @2.4GHz band, 10 dB @5GHz band;

- 1350 b) STA in medium distance: 38 dB @2.4GHz band, 25 dB @5GHz band;
- 1351 c) STA in long distance: 48 dB @2.4 GHz band, 35 dB @5GHz band.
- 1352 2. A Traffic Generator/Analyzer, sending the corresponding Ethernet packets to each STA, connects
- 1353 to the LAN interface (e.g., GE port) of the DUT.
- 1354 3. TCP connection SHALL be used for Ethernet packet transmission in the test.
- 1355

1356 **6.4.1.3 DUT Configuration**

1357 The test SHALL run under the following configuration:

- 1358 1. General configuration for DUT/STA working mode, bandwidth and number of RF chains:
- 1359
- 1360

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

- 1361
- 1362 2. The general configuration SHALL be tested if the configuration is applicable for DUT.

1363 **6.4.1.4 Procedures**

- 1364 1. Configure DUT working mode as 802.11n, operating frequency band as 2.4GHz with default
- 1365 configuration.
- 1366 2. Enable the radios on the STAs with the short distance. Allow STA to associate with the DUT.
- 1367 3. Measure the downlink TCP throughput to each STA, using a test time of 120 seconds. Calculate
- 1368 the summation of downlink TCP throughput of the three STA in short distance. Record the result
- 1369 as “Throughput_S_DL”.Wait for 10 seconds. Measure the uplink TCP throughput to each STA,
- 1370 using a test time of 120 seconds. Calculate the summation uplink TCP throughput of the three
- 1371 STA in short distance. Record the result as “Throughput_S_UL”.
- 1372 4. Enable the radios on the STAs with the medium distance. Allow STA to associate with the DUT.
- 1373 Measure the downlink TCP throughput to each STA, using a test time of 120 seconds. Calculate
- 1374 the summation of downlink TCP throughput of all STA (three STA in short distance and the three
- 1375 STA in medium distance). Record the result as “Throughput_SM_DL”.Wait for 10 seconds.
- 1376 Measure the uplink TCP throughput to each STA, using a test time of 120 seconds. Calculate the
- 1377 summation of uplink TCP throughput of all STA (the three STA in short distance and the three
- 1378 STA in medium distance). Record the result as “Throughput_SM_UL”.
- 1379 5. Enable the radios on the STAs with the long distance. Allow STA to associate with the DUT.
- 1380 Measure the downlink TCP throughput to each STA, using a test time of 120 seconds. Calculate
- 1381 the summation of all STA (downlink TCP throughput of the three STA in short distance, the three
- 1382 STA in medium distance and the three STA in long distance). Record the result as
- 1383 “Throughput_SML_DL”.Wait for 10 seconds. Measure the uplink TCP throughput to each STA,

- 1384 using a test time of 120 seconds. Calculate the summation of uplink TCP throughput of all STA
 1385 (the three STA in short distance, the three STA in medium distance and the three STA in long
 1386 distance). Record the result as “Throughput_SML_UL”.
- 1387 6. Set the working mode of DUT to 802.11ac according to Table 31, and bandwidth to 80 MHz if
 1388 applicable, and repeat Step 2- 5.
 - 1389 7. Set the working mode of DUT to 802.11ax over 2.4 GHz according to Table 31, and bandwidth
 1390 to 20 MHz if applicable, and repeat Step 2- 5.
 - 1391 8. Set the working mode of DUT to 802.11ax over 5 GHz according to Table 31, and bandwidth to
 1392 80 MHz if applicable, and repeat Step 2- 5.

1394 **Note 1:** The test result MAY be slightly affected by the capability of Peer STA. The test MAY be conducted
 1395 with multiple peer STAs with chipsets from different vendors. The calculated average throughput then is
 1396 averaged again in the dimension of chipset.

1397 **Note 2:** Distance MAY be simulated by using attenuators between RF output and antenna of Wi-Fi device.
 1398

1399 **6.4.1.5 Metrics (Pass/Fail Criteria)**

1400 In order to pass the test case, the recorded results SHALL meet the Pass/Fail Criteria, described as
 1401 following:

- 1402 a) Throughput of the Peer STAs SHALL satisfy the requirement in Table 32

1403 **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

1405

1406 **6.4.2 Multiple Association/Disassociation Stability Test**

1407 **6.4.2.1 Introduction**

1408 Multiple association/disassociation stability test intends to measure stability of Wi-Fi device under a
 1409 dynamic environment with frequent change of connection status.

1410
 1411 This test SHALL be MANDATORY for the test plan.

1412

1413 **6.4.2.2 Setup**

- 1414 1. The test setup (shown in Figure 6) SHALL locate in the anechoic shielded chamber (see section
 1415 5.2.1 and 5.2.2).
 1416 2. 16 peer STAs SHALL be connected to the dedicated operating frequency band (2.4 GHz or 5
 1417 GHz) and in a short distance of 2 meter to the DUT (For 2.4 GHz band, 2 meter free space of
 1418 wireless channel leads to 46 dB attenuation). The test is only conducted for one operating
 1419 frequency band in each test circle.
 1420 3. UDP connection SHALL be used for Ethernet packet transmission in the test.
 1421

1422 **6.4.2.3 DUT Configuration**

1423 The test SHALL run under the following configuration:

- 1424 1. General configuration for DUT/STA working mode, bandwidth and number of RF chains:
 1425

1426 **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

- 1427
 1428 2. The general configuration SHALL be tested if the configuration is applicable for DUT.
 1429

1430 **6.4.2.4 Procedures**

- 1431 1. Configure the working mode of DUT as 802.11n, operating frequency as 2.4GHz with the default
 1432 configuration.
 1433 2. 8 STAs are picked for sending/receiving packet while the other 8 STAs are picked to do
 1434 association/re-association process during the test. Establish the LAN connection and allow STA
 1435 to associate with the DUT. Enable downlink UDP flow (4 Mbps @2.4GHz and 8 Mbps @5GHz)
 1436 from DUT to each STA.
 1437 3. Continue monitoring the traffic flow of each STA by recording the UDP flow rate every second.
 1438 4. Disassociate the rest peer STAs. Wait for 30 seconds. Re-associate the STAs simultaneously.
 1439 5. Configure the working mode of DUT as 802.11ac, operating frequency band as 5 GHz and the
 1440 channel bandwidth to 80 MHz, respectively. Wait for 10 seconds, repeat Steps 2-4.
 1441 6. Configure the working mode of DUT as 802.11ax over 2.4 GHz, operating frequency band as 5
 1442 GHz and the channel bandwidth to 20 MHz, respectively. Wait for 10 seconds, repeat Steps 2-4.

- 1443 7. Configure the working mode of DUT as 802.11ax over 5 GHz, operating frequency band as 5
1444 GHz and the channel bandwidth to 80 MHz, respectively. Wait for 10 seconds, repeat Steps 2-4.

1445

1446 **Note:** The test result MAY be slightly affected by the capability of Peer STA. The test MAY be conducted
1447 with multiple peer STAs with chipsets from different vendors.
1448

1449 **6.4.2.5 Metrics (Pass/Fail Criteria)**

1450 In order to pass the test case, the recorded results SHALL meet the Pass/Fail Criteria, described as
1451 following:

- 1452 a) The disassociation/association does not affect the performance of other peer STAs.
1453 b) UDP traffic rate is at least 99% of the configured rate for each STA.
1454 c) UDP packet loss rate SHALL be less than 0.01%.
1455

1456 **6.4.3 Downlink MU-MIMO Performance Test**

1457 **6.4.3.1 Introduction**

1458 Downlink MU-MIMO Performance Test intends to verify the performance of Wi-Fi device when
1459 Downlink MU-MIMO is applied. This best represents a typical deployment, where stations may only
1460 support 1x1 or 2x2 RF chain configurations. The test is only applicable to the Wi-Fi device
1461 supporting the 802.11ac/ax. Downlink MU-MIMO capability is also sometimes referred to as
1462 802.11ac Wave 2. The DUT SHALL support 802.11ac/ax MU-MIMO and at least 4 spatial streams.
1463

1464 This test SHALL be conditionally MANDATORY for the test plan, if the DUT supports Downlink
1465 MU-MIMO, with at least 3 spatial streams (NSS=3) for each band to be tested, the test is required.

1466 **6.4.3.2 Setup**

- 1467 1. The test setup (see Figure 8) SHALL locate in the anechoic shielded chamber (see section 5.2.1
1468 and 5.2.2).
- 1469 2. The DUT and engaged peer STAs SHALL support 802.11ac or 802.11ax and MU-MIMO. One
1470 STA (STA 1) supports maximum two spatial streams while two STAs (STA 2 and STA 3) support
1471 only one spatial stream. All STAs are located in the distance of 2 meter to the DUT (For 5.2 GHz
1472 band, 2-meter free space of wireless channel leads to 52.8 dB attenuation) and are placed at
1473 different angles relative to the DUT, ideally more than 45 degrees apart.
- 1474 3. A Traffic Generator/Analyzer, sending the Ethernet packet to each peer STA, connects to the
1475 LAN interface of the DUT.
- 1476 4. TCP connection SHALL be used for Ethernet packet transmission in the test.
1477

1478 **6.4.3.3 DUT Configuration**

1479 The test SHALL run under the default configuration and SHALL ensure the following configuration
1480 settings are also applied:

- 1481 a) 802.11ac Downlink MU-MIMO *enable*
 - 1482 b) 802.11ax 2.4 GHz Downlink MU-MIMO *enable*, OFDMA *disabled*
 - 1483 c) 802.11ax 5 GHz Downlink MU-MIMO *enable*, OFDMA *disabled*
- 1484

1485 **6.4.3.4 Procedures**

- 1486 1. Establish the setup by using the default configuration as detailed above.
 - 1487 2. Associate STA 1 with DUT. Establish the LAN connection and wait for 10 seconds.
 - 1488 3. Measure the downlink TCP throughput to STA1, using a test time of 120 seconds. Record this
1489 value as STA1_throughput_1.
 - 1490 4. Disassociate STA1. Wait for 10 seconds. Associate STA 2 with DUT. Wait for 10 seconds.
1491 Measure the downlink TCP throughput to STA2, using a test time of 120 seconds. Record this
1492 value as STA2_throughput_1.
 - 1493 5. Disassociate STA 2. Wait for 10 seconds. Associate STA 3 with DUT. Wait for 10 seconds.
1494 Measure the downlink TCP throughput to STA 3, using a test time of 120 seconds. Record this
1495 value as STA3_throughput_1.
 - 1496 6. Associate STA 1 and STA 2 with the DUT (STA 3 remains associated). Simultaneously measure
1497 the downlink TCP throughput to all STA, using a test time of 120 seconds. Record these values
1498 as STA1_throughput_2, STA2_throughput_2 and STA3_throughput_2.
 - 1499 7. Disable DL MU-MIMO and wait for 10 seconds. Measure the downlink TCP throughput to each
1500 STA, using a test time of 120 seconds. Record these values as STA1_throughput_3,
1501 STA2_throughput_3 and STA3_throughput_3. If the DUT does not support this operation, this
1502 step and the associated test metric SHALL NOT apply.
 - 1503 8. Repeat steps 1 through 7 for each DUT configuration listed above in section 6.4.3.3.
- 1504

1505 **6.4.3.5 Metrics (Pass/Fail Criteria)**

1506 In order to pass the test case, the recorded results SHALL meet the Pass/Fail Criteria, described as
1507 follows:

- 1508 a) The sum of STA1_throughput_2, STA2_throughput_2, and STA3_throughput_2 SHALL be at
1509 least 45% of the sum of STA1_throughput_1, STA2_throughput_1, and STA3_throughput_1.
 - 1510 b) The sum of STA1_throughput_2, STA2_throughput_2, and STA3_throughput_2 SHALL be
1511 greater than the sum of STA1_throughput_3, STA2_throughput_3, and STA3_throughput_3.
1512 This test metrics SHALL only apply to the DUT that supports the configuration to disable DL
1513 MU-MIMO.
- 1514

1515 **6.5 Stability/Robustness**

1516 **6.5.1 Long Term Stability Test**

1517 **6.5.1.1 Introduction**

1518 Long term stability test intends to measure the stability performance of Wi-Fi device under stresses
1519 that would typically been seen under heavy user load, such as watching multiple 4k video streams.
1520 Throughput and connection availability are continuously monitored over a period of 4 hours, during
1521 which time, the performance must remain steady. Testing is conducted in multiple bands (2.4 GHz
1522 and 5 GHz) simultaneously.

1523
1524
1525 This test SHALL be MANDATORY for the test plan.
1526

1527 **6.5.1.2 Setup**

- 1528 1. The test setup (See Figure 6) SHALL be located in the anechoic shielded chamber (see section
1529 5.2.1 and 5.2.2).
 - 1530 2. A total of 4 STAs SHALL be used during the test, with 2 STAs connecting within the 2.4 GHz
1531 band and 2 STAs connecting within the 5 GHz band.
 - 1532 3. One STA in each band SHALL be used to perform traffic performance measurements, while the
1533 other STA in the band SHALL be used to periodically associate and disassociate from the DUT.
 - 1534 4. A Traffic Generator/Analyzer, establishing the Ethernet packets transmission to the STA
1535 (allocated to receive packets), connects to the LAN interface (e.g., GE port) of the DUT.
 - 1536 5. UDP connections, operating at a fixed bitrate SHALL be used to measure the performance of
1537 the DUT.
- 1538
1539

1540 **6.5.1.3 DUT Configuration**

1541 The test SHALL run under the following configurations:

- 1542 1. 802.11n and 802.11ac
- 1543 2. 802.11ax 2.4 GHz and 802.11ax 5 GHz

1544
1545 If the DUT does not include multiple radios (i.e. the DUT does not support either the 2.4 or 5 GHz
1546 band), the test SHALL be run with only the single band in operation, with a total of 2 STAs.

1547
1548

1549 **6.5.1.4 Procedures**

- 1550 1. Configure the DUT for the first operating configuration described above.
- 1551 2. Configure the 2 STAs connecting to the 2.4 GHz band to associate with the DUT.
- 1552 3. Configure the 2 STAs connecting to the 5 GHz band to associate with the DUT.
- 1553 4. Wait for 60 seconds for the system to reach a steady state.

- 1554 5. Configure two downlink UDP throughput measurements to run for 15 minutes each using a bit
1555 rate of 50 Mbps through one 2.4 GHz STA and one 5 GHz STA. While this throughput
1556 measurement is running perform the following actions:
- 1557 i. Wait 5 minutes
 - 1558 ii. Toggle the association state of the second STA in each band (i.e. if the STA is
1559 currently associated to the DUT, cause it to disassociate; or if it is disassociated, cause
1560 it to associate).
- 1561 6. Record the number of lost UDP packets for each downlink measurement, recording the
1562 measurement as PACKET_LOSS_[24 or 5]_GHZ_INTERVAL_n, where the band is indicated
1563 as 2.4 or 5 GHz and n represents the n'th measurement interval. Calculate the
1564 PACKET_LOSS_RATIO_[24 or 5]_GHZ_INTERVAL_n as the number of lost packets divided
1565 by the total number of packets transmitted.
- 1566 7. Repeat steps 4 and 5 for a total of 16 measurement intervals (4 hours of testing).
- 1567 8. Repeat steps 1 through 6 for each DUT configuration defined above.
- 1568
- 1569

1570 6.5.1.5 Metrics (Pass/Fail Criteria)

1571 In order to pass the test case, the recorded results SHALL meet the Pass/Fail Criteria, described as
1572 following:

- 1573 1. For each measurement interval, the packet loss ratio SHALL be less than or equal to 1E-4.

1574
1575

1576 6.5.2 AP Coexistence Test

1577 6.5.2.1 Introduction

1578 AP coexistence test intends to verify Wi-Fi device performance with existence of alien AP. The
1579 alien AP in the test SHALL support the same Wi-Fi standard (802.11n/802.11ac/802.11ax).

1580

1581 This test SHALL be MANDATORY for the test plan.

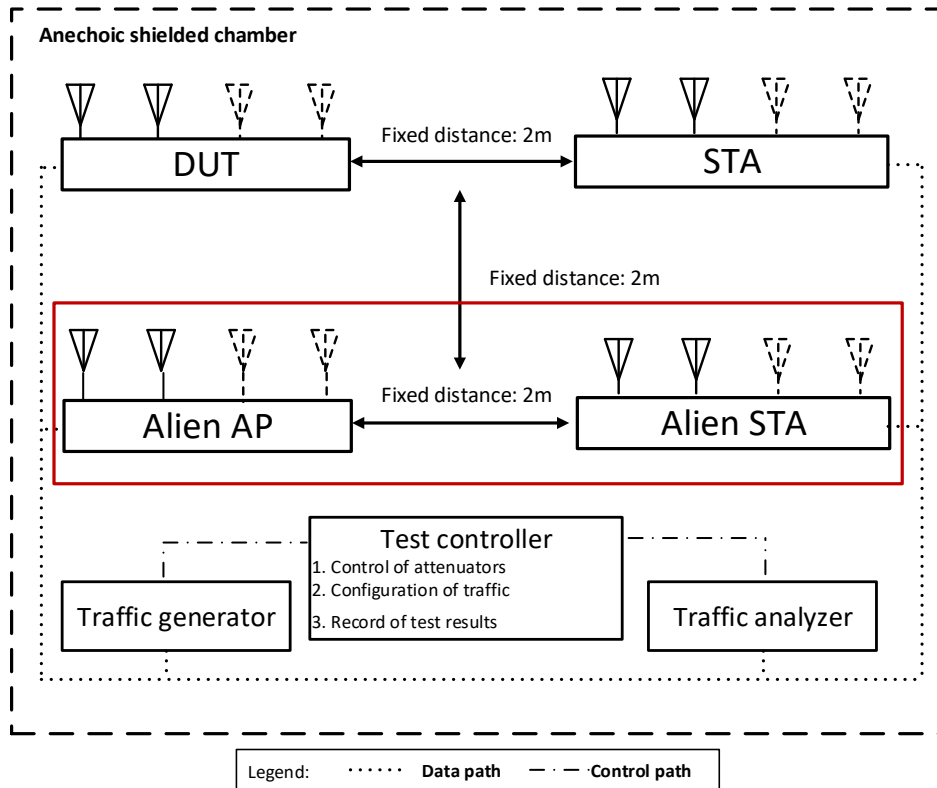
1582

1583 **Note:** This test case implements a simplified scenario where the alien network presents a 50%
1584 utilization/contention with the DUT.

1585 6.5.2.2 Setup

- 1586 1. The test setup (show in Figure 12) SHALL locate in the anechoic shielded chamber (see section
1587 5.2.1 and 5.2.2), DUT and peer STA is in a distance of 2 meters.
- 1588 2. A host sends/receives the Ethernet packets/IP packets to DUT. The Peer STA receives/sends
1589 the Wi-Fi packets from/to the DUT through air interface.
- 1590 3. The host SHALL send the Ethernet packets/IP packets at the maximum rate which the DUT can
1591 achieve theoretically.

- 1592 4. A set of Wi-Fi interfaces/radios, supporting the same Wi-Fi standard
- 1593 (802.11n/802.11ac/802.11ax), are used to generate the alien network interference, per the
- 1594 configurations described in Table 35. The QoS settings on the alien network SHALL match
- 1595 those on the DUT.
- 1596 5. TCP connection SHALL be used for Ethernet packet transmission in the test.
- 1597 6. The Alien AP SHALL be the same manufacturer, model, and firmware version of the DUT and
- 1598 SHALL be configured identically to the DUT except for the settings specified in Table 26 and
- 1599 the SSID that SHALL be set to "BBF_Wi-Fi_Perf_Test_Alien".
- 1600
- 1601



1602
1603
1604

Figure 12: Test Setup of AP Coexistence Test

1605 **6.5.2.3 DUT Configuration**

- 1606 The test SHALL run under the following configuration:
- 1607 1. General configuration for DUT/STA working mode, bandwidth and number of RF chains:

1608 **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

1609

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.		

1610
1611
1612
1613
1614
1615
1616
1617

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

- 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: <ol style="list-style-type: none"> If channels other than the default channels are used, the separation of the center frequencies of the channels should be the same as the separation of the center frequencies as defined using the default channels, and the bandwidths should be the same as in the default test case. This intends to emulate the effects of an overlapped channel (5 GHz alien configuration is set to use a 40 MHz channel, while the DUT continues to use an 80 MHz channel). 				

1618

1619 6.5.2.4 Procedure

- 1620 1. Configure the working mode of DUT to 802.11n, operating frequency band to 2.4 GHz with
1621 default configuration. Allow peer STA registers the DUT.
- 1622 2. The channel of alien network SHALL be set to the same channel as DUT.
- 1623 3. Keep the alien network radios shutdown (not transmitting any signals).
- 1624 4. Wait for 10 seconds. Measure the downlink TCP throughput to peer STA, using a test time of 120
1625 seconds. Record this measurement as THROUGHPUT_SHORT_DUT.
- 1626 5. Enable the alien network radios. The alien network SHALL be configured according to Table 35.
1627 The alien network will transmit beacon frames according to the default configuration settings of
1628 5.3.3.
- 1629 6. Wait for 10 seconds. Measure the downlink TCP throughput to peer STA, using a test time of 120
1630 seconds. Record this measurement as THROUGHPUT_SHORT_DUT_1.
- 1631 7. Configure the alien network to utilize 50% of the available “air time”. This can be achieved by
1632 packet transmission using the alien network of 1500-byte packets at one of the following rates,
1633 depending on the configuration used for the alien network and the wireless MSC rate selected by
1634 the transmitter: 32 Mbps for 802.11n 20MHz channels with 1 spatial stream, 90 Mbps for
1635 802.11ac 40MHz with 1 spatial stream, 195 Mbps for 802.11ac 80MHz with 1 spatial stream, 65
1636 Mbps for 802.11n 20MHz channels with 2 spatial streams, 180 Mbps for 802.11ac 40MHz with
1637 2 spatial streams, or 390 Mbps for 802.11ac 80MHz with 2 spatial streams.

- 1638 8. Wait for 10 seconds. Measure the downlink TCP throughput to peer STA, using a test time of 120
- 1639 seconds. Record this measurement as THROUGHPUT_SHORT_DUT_2.
- 1640 9. Change the channel configuration of alien AP according to Table 35 until all the configuration
- 1641 has been tested. Repeat Step 8. Stop the packet transmission for alien network.
- 1642 10. Shut down the radios on the alien network.
- 1643 11. Repeat steps 2 to 10 for each additional configuration listed in Table 34 above.

1644 **6.5.2.5 Metrics (Pass/Fail Criteria)**

1645 In order to pass the test case, the recorded results SHALL meet the Pass/Fail Criteria, described as
 1646 following:

- 1647 a) The average throughput measured SHALL satisfy the requirements in Table 36:

1648 **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.

1650

1651 **6.5.3 Automatic Channel Selection Test**

1652 **6.5.3.1 Introduction**

1653 When operating in environments with multiple Wi-Fi based networks the AP may be able to more
 1654 reliably select the channel with the lowest level of impairments from the adjacent networks
 1655 compared to a less knowledgeable end user. The test verifies the DUT (AP) will select a Wi-Fi
 1656 channel that is not presently utilized by other networks and will alter this channel on subsequent
 1657 reboots, if the environment has changed (i.e. the channels utilized by the adjacent network has
 1658 changed).

1659 Note, this test is not intended to verify avoidance of radar or other non-Wi-Fi signals or usage of the
 1660 same frequencies by other technology.

1661
 1662 This test SHALL be OPTIONAL for the test plan.

1663 **6.5.3.2 Setup**

- 1664 1. The test setup (shown in Figure 12) SHALL be located in the anechoic shielded chamber (see
 1665 section 5.2.1 and 5.2.2), using 2 stations and 1 additional AP.
 1666 2. Configure the DUT to enable automatic channel selection for both its 2.4 GHz and 5 GHz
 1667 radios. Note, ensure these settings are persistently saved on the DUT.
 1668 3. Configure one station to enable only the 2.4 GHz band, use the SSID and password for the test
 1669 network per section 5.3.2.
 1670 4. Configure the additional AP to use 2.4 GHz Wi-Fi channel 6, 20 MHz channel bandwidth, and
 1671 the settings in Table 37 below.
 1672 5. Configure the second station to associate to the additional AP using the settings in Table 37
 1673 below.
 1674 6. The Ethernet traffic generator / analyzer is connected to the additional AP and STA.
 1675
 1676

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>

1677

1678 **6.5.3.3 DUT Configuration**

1679 The test SHALL run under the following configuration:

- 1680 1. The DUT works in different modes:
 1681 i. 802.11n
 1682 ii. 802.11ac
 1683 iii. 802.11ax over 2.4 GHz
 1684 iv. 802.11ax over 5 GHz

1685 **6.5.3.4 Procedures**

- 1686 1. Power off the DUT.
 1687 2. Allow the second station to associate to the additional AP.
 1688 3. Configure the Ethernet traffic generator to run a continuous TCP throughput measurement,
 1689 causing the devices to continuously transmit over the Wireless link between the second STA
 1690 and AP.
 1691 4. Power on the DUT and allow the first station to associate with the DUT.

- 1692 5. Record the channel used by the DUT.
- 1693 6. Repeat steps 1 through 5, with the additional AP configured to use 2.4 GHz channels 1 and
- 1694 11.
- 1695 7. Repeat steps 1 through 5, with the additional AP configured to use 2.4 GHz channel 1 and
- 1696 40 MHz bandwidth.
- 1697 8. Repeat steps 1 through 5, using the 5 GHz band, with the additional AP configured to
- 1698 channels 42, 58, 106, and 122. The additional AP should be configured to use a channel
- 1699 bandwidth of 80 MHz.

1700 **6.5.3.5 Metrics (Pass/Fail Criteria)**

1701 In order to pass the test case, the recorded results SHALL meet the Pass/Fail Criteria, described as

1702 following:

- 1703 1. The DUT SHALL select a channel that is not the same as the channel the Additional AP is
- 1704 operating on and the selected channel SHALL not overlap with the channel the Additional
- 1705 AP is operating on. If the DUT selects the same, or an overlapping channel, the test point
- 1706 SHALL be considered a failure.

1707 **Table 38: Automation Channel Selection Test Requirements**

1708

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.		

1709

1710

1711 **Appendix I. Instantiations of Test Setups**

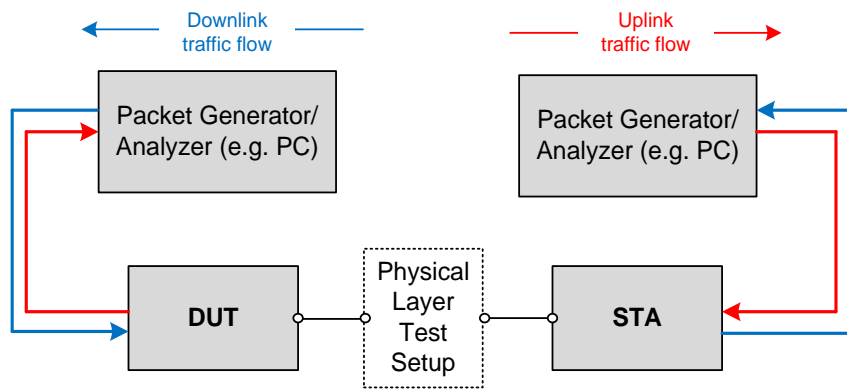
1712 Appendix I provides instantiations of test setups as guidelines for execution of the test plan. The
1713 selection of the test equipment is out of scope of this document.

1714
1715

1716 **I.1 Test setup by using IP packet through TCP or UDP**

1717 If TCP/UDP flow is required in the test, the Packet Generator/Analyzer SHALL be IP traffic
1718 generator/analyzer. Performance statistics of TCP flow SHOULD be conducted from the TCP flow
1719 sender (packet generator) while a performance statistics of UDP flow as a report SHOULD be sent
1720 from the receiver (packet analyzer) to sender (packet generator).

1721



1722
1723

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

1724
1725

1726 Figure 13 shows typical examples when TCP/UDP flows are used in the test. Two independent Packet
1727 Generators/Analyzers are utilized for packet generation/analysis. In this case, STA/STAs SHALL
1728 provide interface to receive/forward packets from/to packet generation/analysis in STA side.

1729

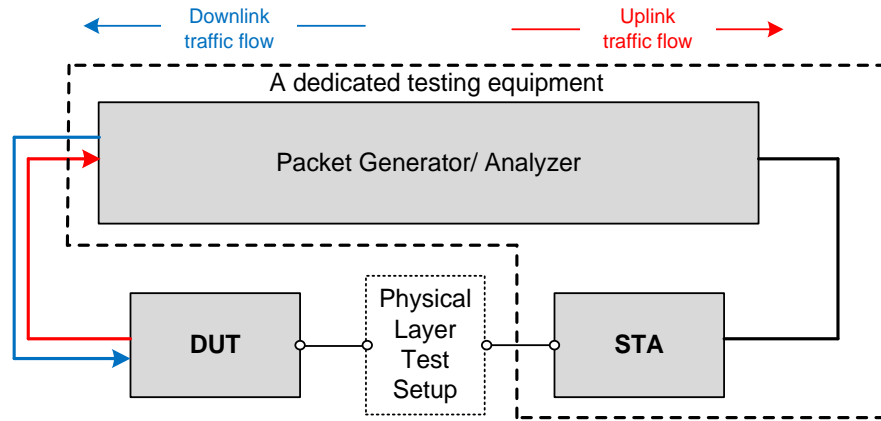


Figure 14: Test setup by using TCP/UDP flows with the dedicated testing equipment

1730
1731
1732
1733
1734

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.

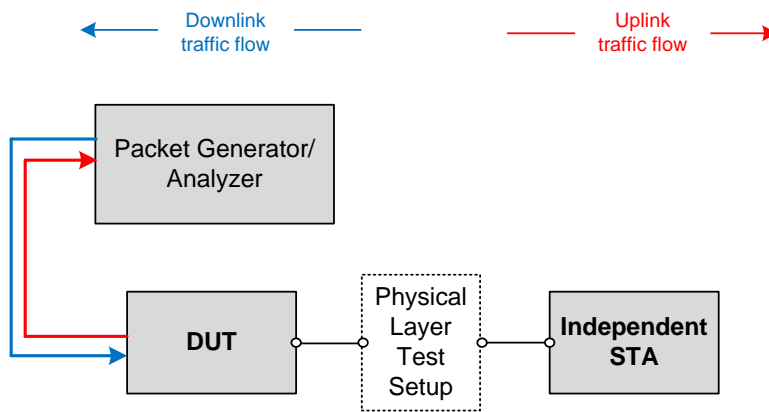


Figure 15: Test setup by using TCP/UDP flows with an independent STA

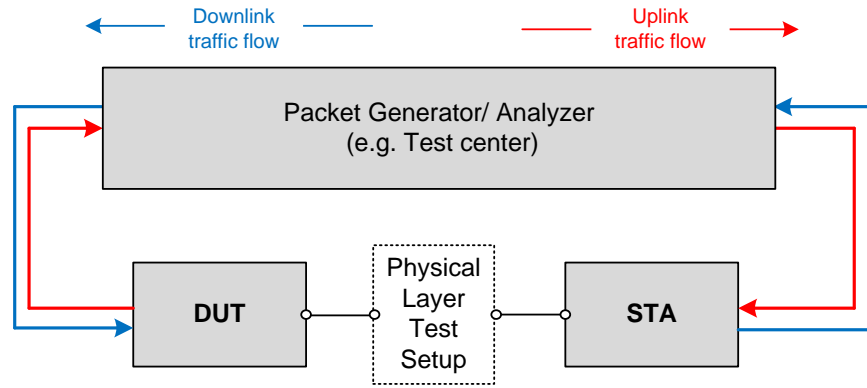
1735
1736
1737
1738
1739
1740
1741
1742
1743
1744
1745
1746
1747
1748

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.

1749 Figure 16 shows a typical example when level-2 Ethernet flows are used in the test. A common Packet
1750 Generator/Analyzer provide bidirectional packet generation/reception. In this case, STA/STAs
1751 SHALL provide interface to receive/forward packets from/to packet generation/analysis in STA side.



1752
1753 **Figure 16: Test Setup by using level-2 Ethernet flows with a common Packet**
1754 **Generator/Analyzer**

1755
1756
1757
1758

1759 **Appendix II. Test Cases For Further Study**

1760 The following test cases are optional and for further study. Specific pass / fail requirements for
 1761 these cases may not yet be available. In these cases, testers are encouraged to provide the
 1762 measurement data for information within test reports.
 1763

1764 **II.1 Repeated Wi-Fi Throughput Performance Test**

1765 **II.1.1 Introduction**

1766 This test case measures the throughput performance of a Wi-Fi system, where the DUT is
 1767 considered to be the combination of a “base AP” and a “Wi-Fi repeater.” The “base AP” is defined
 1768 as the AP devices connected to the wired network connection of the traffic generator and analyzer,
 1769 while the “Wi-Fi repeater” has only RF connections to the both the “base AP” and the STA. During
 1770 this test, the STA is only connected to the “Wi-Fi Repeater.” The Wi-Fi connection between the
 1771 “base AP” and “Wi-Fi repeater” is configured to enable all supported radios and protocols, allowing
 1772 the two devices to adapt the Wi-Fi connection according to their internal logic. The STA’s RF
 1773 connection is configured to a specific operating mode. The back-haul link between “base AP” and
 1774 the “Wi-Fi Repeater” is expected to be at least 802.11ac Nss=2 or better in performance for this test.
 1775

1776 This test SHALL be OPTIONAL for the test plan and is for further study.
 1777

1778 **II.1.2 Setup**

- 1779 1. The test setup shown in Figure 3 “Wi-Fi Mesh Multiple Chamber Implementation” SHALL be
 1780 used for this test.
 1781 2. The “base AP” SHALL be placed in Shielded Chamber 1, and connected to the traffic generator.
 1782 3. The “Wi-Fi Repeater SHALL be placed in Shielded Chamber 2.
 1783 4. The Attn A set SHALL be configured to 10 dB.
 1784 5. The Attn B set SHALL be configured to 10 dB.
 1785 6. The Attn C set SHALL be configured to at least 60 dB.
 1786 7. The Traffic Generator/Analyzer, capable of sending the Ethernet packets, SHALL be connected
 1787 to the LAN interface (e.g., GE port) of the “base AP” and the STA.
 1788 8. The Traffic Generator/Analyzer SHALL be configured to measure the throughput using TCP
 1789 sessions.
 1790

1791 **II.1.3 DUT Configuration**

1792 The test SHALL be run with the STA configured for each of the operating modes listed in Table 39
 1793 below. For each configuration, a set of attenuation values for Attn B shall be measured.
 1794

1795 **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

1796

1797 **II.1.4 Procedures**

- 1798 1. Configure the STA to operate in the first configuration mode described in Table 39.
 1799 2. Configure Attn B for the first value described in Table 39.
 1800 3. Establish the LAN connection and allow STA to associate with the DUT.
 1801 4. Measure the downlink TCP throughput to the STA, using a test time of 120 seconds.
 1802 5. Measure the uplink TCP throughput to the STA, using a test time of 120 seconds.
 1803 6. Repeat steps 2 through 5 for each attenuation value listed in Table 39 for the configured operating
 1804 mode.
 1805 7. Repeat steps 1 through 6 for each configuration from Table 39 supported by the “Wi-Fi
 1806 Repeater.”

1807

1808 Note: The tester must ensure the STA is connected to the “Wi-Fi Repeater” and not the “Base AP”
 1809 through Attn C.

1810

1811 **II.1.5 Metrics (Pass/Fail Criteria)**

- 1812 1. For each attenuation configuration, the STA MUST be able to associate to the “Wi-Fi repeater.”
 1813 2. For each attenuation configuration, the measured throughput MUST be equal to, or greater than
 1814 the values listed in the tables below, for the required number of measurement points identified
 1815 with the table.

1816

1817 EDITOR’S NOTE: When developing the pass/fail metrics, the case should be considered where the
 1818 back-haul link is 802.11ac Nss=2, while the front-haul link to the STA is 802.11ax Nss=2. This case
 1819 will exist for some operators as systems roll out and should allow for those devices to pass.

1820

1821 **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 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

1822

1823 **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 Study	For Further Study	For Further Study	For Further Study

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

1824
1825

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 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

1826
1827

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 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

1828
1829
1830

II.2 Basic Roaming Performance Test

II.2.1 Introduction

1833 This test case attempts to measure the roaming performance of the STA roaming between Wi-Fi
1834 connections of the “base AP” and the “Wi-Fi repeater.” The “base AP” is defined as the AP devices
1835 connected to the wired network connection of the traffic generator and analyzer, while the “Wi-Fi
1836 repeater” has only RF connections to the both the “base AP” and the STA. The roaming
1837 performance is defined as the duration of time the STA is disconnected from the network (not able
1838 to send or receive a packet from the Ethernet traffic generator / analyzer).

1839
1840 This test SHALL be OPTIONAL for the test plan and is for further study.

1841

II.2.2 Setup

- 1842
- 1843 1. The test setup shown in Figure 3 “Wi-Fi Mesh Multiple Chamber Implementation” SHALL be
1844 used for this test.
 - 1845 2. The “base AP” SHALL be placed in Shielded Chamber 1, and connected to the traffic generator.

- 1846 3. The “Wi-Fi Repeater SHALL be placed in Shielded Chamber 2.
- 1847 4. The Attn A set SHALL be configured to 10 dB.
- 1848 5. The Attn B set SHALL be configured to 10 dB.
- 1849 6. The Attn C set SHALL be configured to 60 dB.
- 1850 7. The Traffic Generator/Analyzer, capable of sending the Ethernet packets, SHALL be connected
- 1851 to the LAN interface (e.g., GE port) of the “base AP” and the STA.
- 1852 8. The Ethernet traffic generator is configured to iperf3, or an equivalent substitute, to transmit one
- 1853 stream of 1460-byte UDP packets at 1 Mbps from the STA. The STA MUST NOT “buffer”
- 1854 packets while Wi-Fi is disconnected for the roaming event.
- 1855 9. The STA SHALL have 802.11v (BSS Transition Management Messages) enabled. The DUT
- 1856 MAY, but is not required, to support 802.11v.
- 1857

II.2.3 DUT Configuration

1859 The test SHALL be run with the STA configured for each of the operating modes listed in Table 44
 1860 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

1862
 1863

II.2.4 Procedures

- 1865 1. Configure the “base AP,” “Wi-Fi repeater,” and STA to operate in the first configuration mode
- 1866 described in Table 44. ^{Note 1}
- 1867 2. Configure Attn B to 10 dB and Attn C to 60 dB.
- 1868 3. Establish the LAN connection and allow STA to associate with the DUT. Verify the STA is
- 1869 associated with the “Wi-Fi repeater.”
- 1870 4. Enable the uplink UDP transmission from the STA.
- 1871 5. Decrease the value of Attn C by 1 dB
- 1872 6. Wait 2 seconds
- 1873 7. Increase the value of Attn B by 1 dB
- 1874 8. Wait 2 second
- 1875 9. Repeat steps 5 through 8 until Attn B is configured to 60 dB.
- 1876 ^{10.} Stop the UDP transmission and record the number of UDP packets that were transmitted by the
- 1877 STA and the number of UDP packets received by the iperf target. ^{Note 2}
- 1878 11. Restart the uplink UDP transmission from the STA.
- 1879 12. Decrease the value of Attn B by 1 dB
- 1880 13. Wait 2 seconds
- 1881 14. Increase the value of Attn C by 1 dB
- 1882 15. Wait 2 second
- 1883 16. Repeat steps 5 through 8 until Attn C is configured to 60 dB.

- 1884 17. Stop the UDP transmission and record the number of UDP packets that were transmitted by the
1885 STA and the number of UDP packets received by the iperf target. ^{Note 2}
1886 18. Repeat steps 1 through 17 for each configuration from Table 44 supported by the “base AP” and
1887 “Wi-Fi repeater.”
1888

Notes:

- 1890 1. The systems are configured to use a single wireless operating mode (i.e. 802.11n @
1891 2.4 GHz, Nss = 2, BW = 20 MHz), to reduce the measurement uncertainty between
1892 test runs, by preventing the case where the STA roamed from one AP to the other,
1893 while also changing operating modes.
1894 2. It is expected for there to be lost UDP packets (i.e. a difference in the total number
1895 of received and transmitted packets), caused by the roaming event. Each UDP
1896 packet represents an “interval” of time the STA was disconnected from the network
1897 and blocked from sending traffic.
1898

II.2.5 Metrics (Pass/Fail Criteria)

- 1900 1. For each roaming event (two per each Wi-Fi Configuration), the total number of dropped UDP
1901 packets (difference between received and transmitted packet counters) MUST be less than
1902 [value is For Further Study].
1903
1904
1905

1906
1907
1908
1909
1910
1911
1912
1913
1914
1915



End of Broadband Forum Working Text WT-398i2