Candela
TECHNOLOGIES

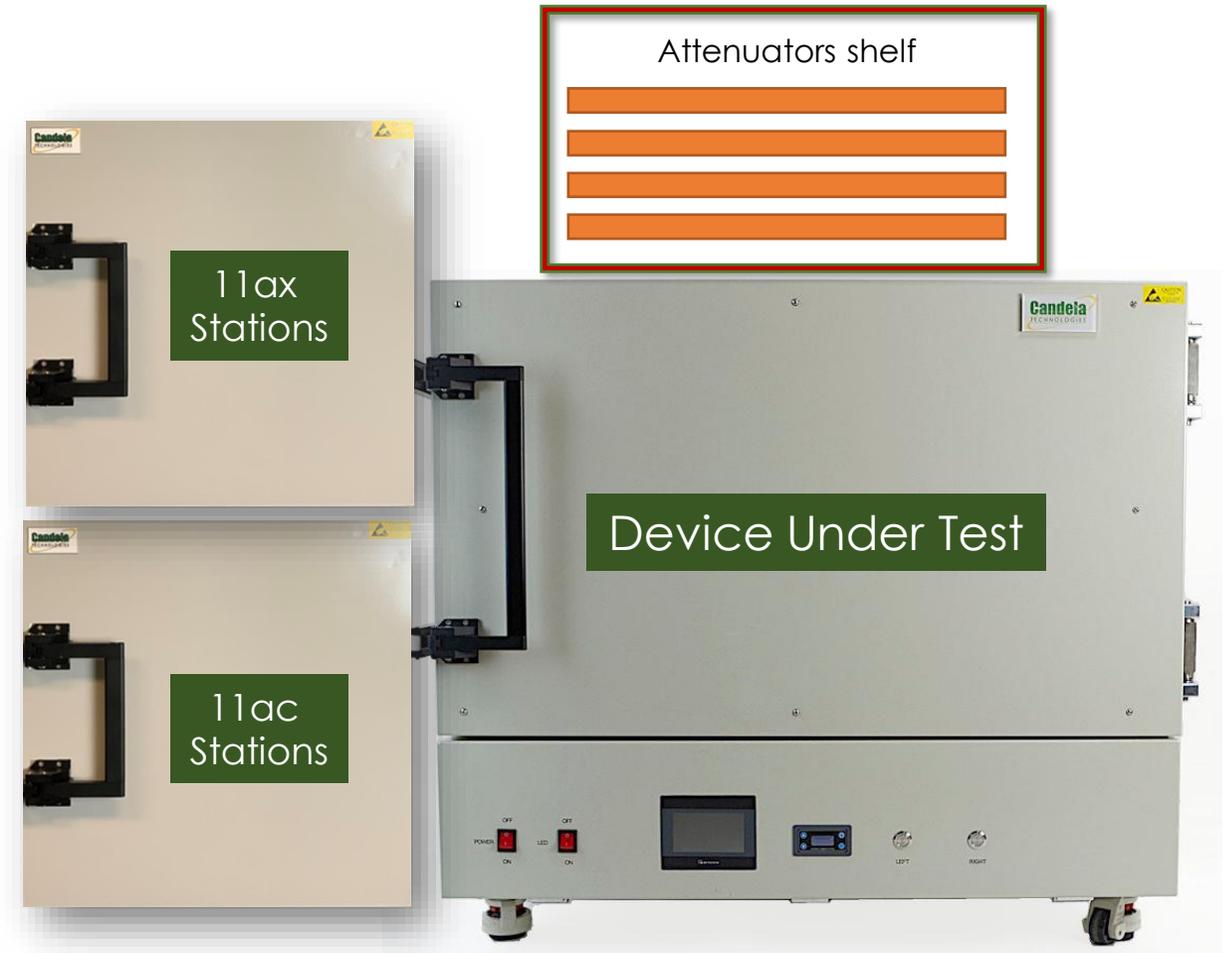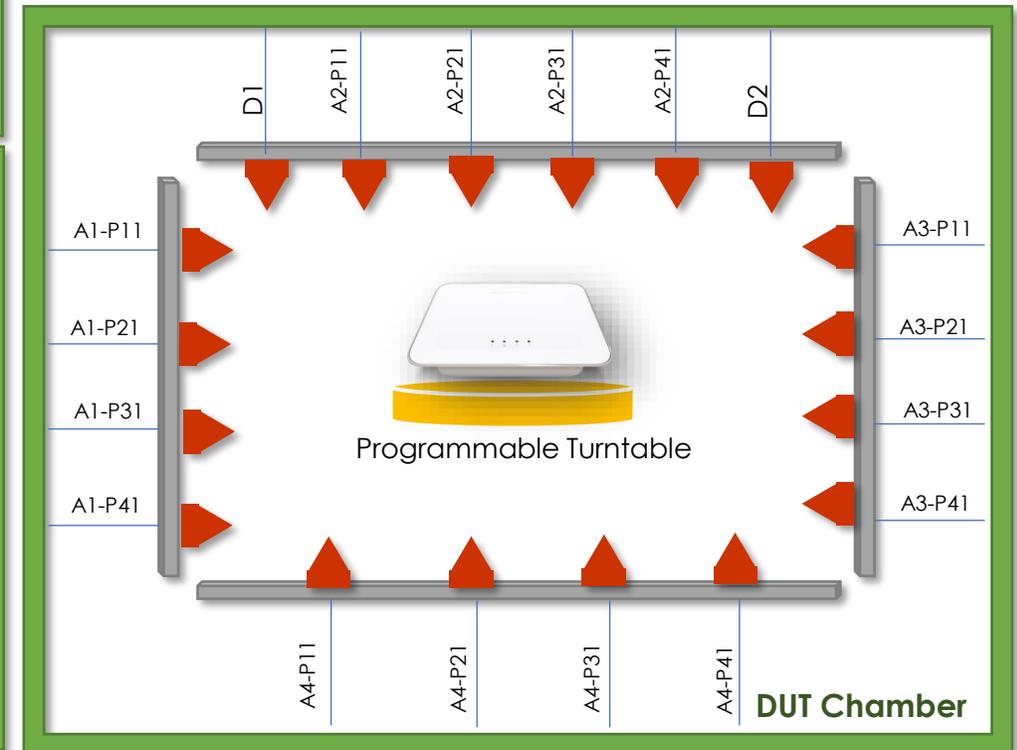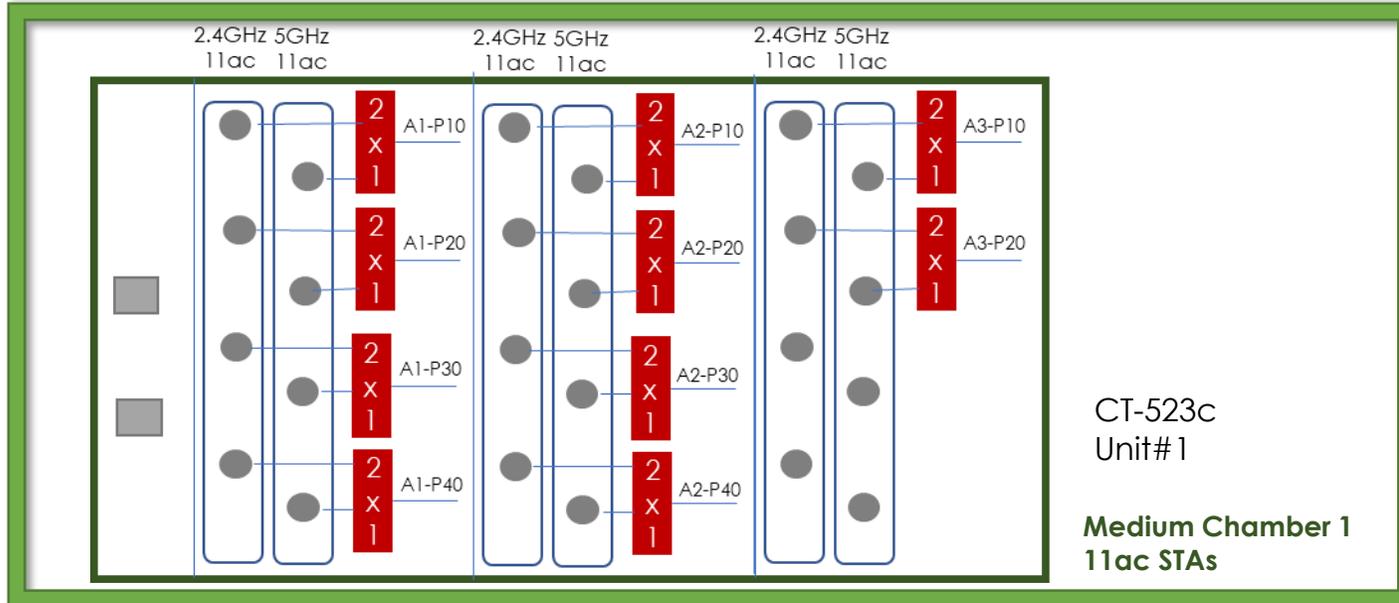Network Testing & Emulation Solutions

✉ sales@candelatech.com
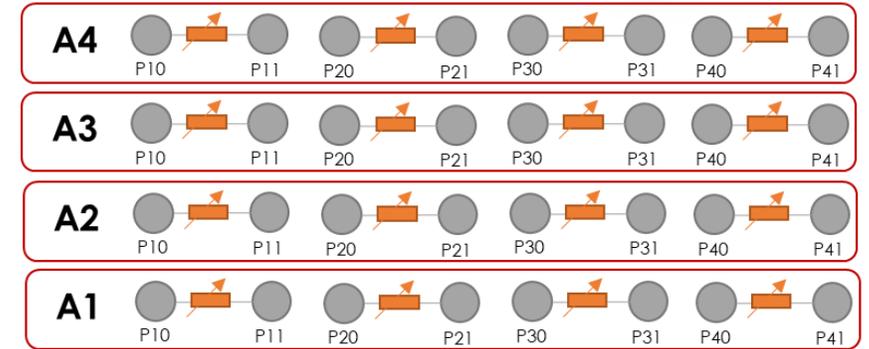☎ 1-360-380-1618

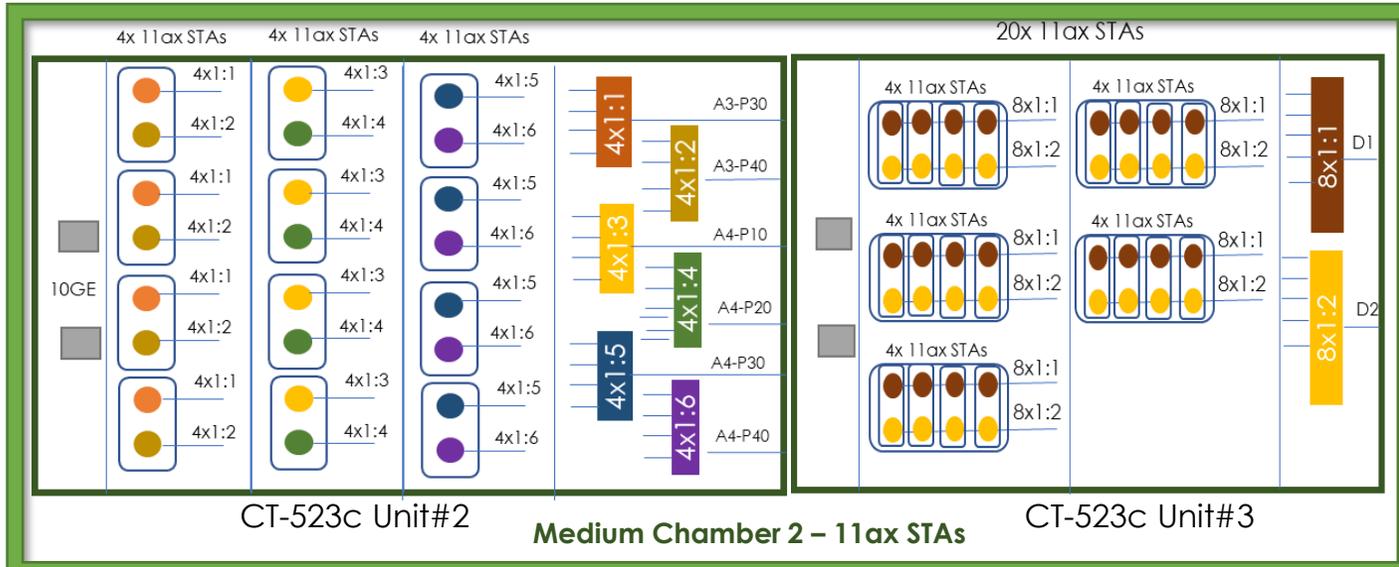# TR-398 Issue 2 Candela Solution

TR-398 Issue 2 Test Cases

- 6.1. RF capability
  - 6.1.1 Receiver Sensitivity Test
- 6.2. Baseline performance
  - 6.2.1 Maximum Connection Test
  - 6.2.2 Maximum Throughput Test
  - 6.2.3 Airtime Fairness Test
  - 6.2.4 Dual-band Throughput Test
  - 6.2.5 Bidirectional Throughput Test
- 6.3. Coverage
  - 6.3.1 Range Versus Rate Test
  - 6.3.2 Spatial consistency test -
  - 6.3.3 802.11ax Peak Performance Test
- 6.4. Multiple STAs Performance
  - 6.4.1 Multiple STAs Performance Test
  - 6.4.2 Multiple Association/Disassociation Stability Test
  - 6.4.3 Downlink MU-MIMO Performance Test
- 6.5. Stability/Robustness
  - 6.5.1 Long Term Stability Test
  - 6.5.2 AP Coexistence Test
  - 6.5.3 Automatic Channel Selection Test

Attenuators shelf

11ax Stations

11ac Stations

Device Under Test

TR-398 Issue2 Full Testbed Wiring Diagram

Medium Chamber 2 – 11ax STAs

CT-523c Unit#2

CT-523c Unit#3

Medium Chamber 1
11ac STAs

CT-523c
Unit#1

DUT Chamber

Programmable Turntable

TR-398 Issue 2 Testbed Images

TR-398 Issue 2 GUI

TR-398 Issue2 Test Report

TR-398v2
WiFi Performance Test Plan

Mon May 10 13:45:38 PDT 2021

Test Setup Information

Device Under Test		
	Name	TR398-DUT-asus
	Software Version	3.0.0.4.386_42819
	Model Number	rtAX-88u
	SSIDs	asus11ax-2 asus11ax-5
	Passwords	hello123 hello123
	BSSIDs	3c:7c:3f:55:4d:60 3c:7c:3f:55:4d:64
	Notes	[BLANK]
Estimated Run Time	4.583 h	
Actual Run Time	3.929 h	

Objective

The TR-398v2 WiFi Performance test plan by the Broadband forum provides a comprehensive set of tests to qualify the performance of WiFi access points (APs) designed for residential and small office environments. Radio performance, Throughput, Connection Stability, Airtime Fairness, AP Co-existence, Mu_MIMO Performance, Spatial Consistency and Long-term Stability are some of the test areas covered in this test plan. The test plan is designed for service providers deploying in home WiFi APs to qualify the APs in the lab before deployment and for equipment makers to test during the development of the APs. Candela Technologies offers a fully automated TR-398v2 test system. The user can select from the list of 11 tests available in the GUI and all selected tests are run fully automated at one click of a button. Measurements are made and compared to the specified PASS/FAIL criteria in the TR-398v2 test plan and this report will show the summary PASS/FAIL results followed more detailed results for each test.

Summary Results

Test	Result	Candela Score	Elapsed	Info
Calibrate 802.11AX Zero Attenuation RSSI	2.4Ghz PASS 5Ghz PASS	100	5.389 m	Attenuator Calibration Step 2.4Ghz Passed 48 / 48 5Ghz Passed 48 / 48
Calibrate 802.11AC Zero Attenuation RSSI	2.4Ghz PASS 5Ghz PASS	95	5.916 m	Attenuator Calibration Step 2.4Ghz Passed 44 / 48 5Ghz Passed 48 / 48
6.1.1 Receiver Sensitivity Test	Skipped	0	0	
6.2.1 Maximum Connection Test (32-STA)	2.4Ghz FAIL 5Ghz FAIL	90	17.126 m	Throughput: 2.4Ghz AC UL 103.56% DL 104.07% Throughput: 2.4Ghz AX UL 2.93% DL 101.93% Throughput: 5Ghz AC UL 103.96% DL 104.36% Throughput: 5Ghz AX UL 51.31% DL 103.29% Passed PER: 245 / 256
6.2.2 Maximum TCP Throughput Test	2.4Ghz FAIL 5Ghz PASS	118	9.953 m	Throughput N 2.4Ghz UL 93.02% DL 119.07% Throughput AX 2.4Ghz UL 114.48% DL 118.58% Throughput AC 5Ghz UL 118.25% DL 126.77% Throughput AX 5Ghz UL 130.26% DL 127.20%
6.2.3 Airtime Fairness Test	2.4Ghz FAIL 5Ghz PASS	89	16.709 m	AC 5Ghz passed 7 / 7 AX 5Ghz passed 7 / 7 N 2.4Ghz passed 7 / 7 AX 2.4Ghz passed 4 / 7
6.2.4 Dual-Band Throughput Test	2.4Ghz PASS 5Ghz FAIL	95	15.267 m	AC 12 / 12 2.4 AX 12 / 12 5Ghz AX 12 / 12
6.2.5 Bidirectional UDP Throughput Test	2.4Ghz FAIL 5Ghz FAIL	8	40.069 m	AC 5Ghz passed 0 / 3 AX 5Ghz passed 0 / 3 N 2.4Ghz passed 0 / 3 AX 2.4Ghz passed 1 / 3
6.3.1 Range Versus Rate Test	2.4Ghz FAIL 5Ghz PASS	82	1.217 h	AC 5Ghz UL 14 / 14 DL 14 / 14 AX 5Ghz UL 14 / 14 DL 14 / 14 N 2.4Ghz UL 7 / 17 DL 16 / 17 AX 2.4Ghz UL 10 / 17 DL 11 / 17
6.3.2 Spatial Consistency Test	Skipped	0	0	
6.3.3 AX Peak Performance TCP Throughput Test	2.4Ghz FAIL 5Ghz FAIL	80	4.821 m	Throughput AX 2.4Ghz UL 76.25% DL 79.06% Throughput AX 5Ghz UL 85.05% DL 83.01%
6.4.1 Multiple STAs Performance Test	2.4Ghz FAIL 5Ghz PASS	91	35.672 m	N 2.4Ghz Passed 6 / 6 AX 2.4Ghz Passed 4 / 6 AC 5Ghz Passed 6 / 6 AX 5Ghz Passed 6 / 6
6.4.2 Multiple Association / Disassociation Stability Test	2.4Ghz FAIL 5Ghz FAIL	99	11.192 m	N 2.4Ghz Passed 723 / 728 AX 2.4Ghz Passed 727 / 728 AC 5Ghz Passed 725 / 728 AX 5Ghz Passed 727 / 728
6.4.3 Downlink MU-MIMO Performance Test	Skipped	0	0	
6.5.2 AP Coexistence Test	Skipped	0	0	
6.5.1 Long Term Stability Test	Skipped	0	0	

Calibrate 802.11AX Zero Attenuation RSSI

Summary

Calibrate the Zero attenuation settings for 2.4 and 5Ghz

Test Procedure

These steps are done for 2.4Ghz and 5Ghz.

1. Create an /a/b/g (legacy) station on each radio (or optionally some other mode and NSS). Legacy mode is used because it is normally sent at full tx-power by the AP. Higher MCS frames are often transmitted below maximum power, especially when using multiple spatial streams.
2. Set all attenuators to 0.
3. Create download connections for each station and run them for 30 seconds.
4. Record Received Signal Strength (RSSI) for each station. This records a decaying average over the last few data frames received, not beacon RSSI.
5. Change attenuation to 8, 15, and 25 and re-run download test and record new RSSI.
6. Record the zero-attenuation RSSI, based on the average over all tested attenuations, in the TR-398v2 Automation setup window.

Pass/Fail Criteria

1. Ensure that relative RSSI is within 3 for each of the different attenuation values.

Candela Score

The Candela Score for Calibration Test is calculated as the percentage of passing sub-tests. As long as the score is 80 or higher and there are no bad outliers in the reported signal calculations the setup is probably working OK. Failures normally indicate a cabling problem or mis-configuration, or in rare cases, a hardware failure in the attenuator or LANforge radios. RF leakage inside of LANforge from adjacent radios and SMA pigtails can cause RSSI variation as well.

cv_udp-2.2-3.wlan2--1.0.20-B	0 bps	1,182 Kbps	32,428	32,428	2,785 88.235
cv_udp-2.2-3.wlan7--1.0.21-A	21,316 Kbps	0 bps	0	34,906	0
cv_udp-2.2-3.wlan7--1.0.21-B	0 bps	787 bps	34,906	34,906	2,779 97.458
cv_udp-2.2-3.wlan12--1.0.22-A	10,817 Kbps	0 bps	0	45,577	0
cv_udp-2.2-3.wlan12--1.0.22-B	0 bps	1,379 Kbps	45,577	45,577	4,039 87.273
cv_udp-2.2-3.wlan17--1.0.23-A	52,591 Kbps	0 bps	0	15,215	0
cv_udp-2.2-3.wlan17--1.0.23-B	0 bps	588 bps	15,215	15,215	1,569 97.048
cv_udp-2.2-3.wlan3--1.0.24-A	33,072 Kbps	0 bps	0	21,682	0
cv_udp-2.2-3.wlan3--1.0.24-B	0 bps	1,968 Kbps	21,682	21,682	3,087 87.432
cv_udp-2.2-3.wlan8--1.0.25-A	38.71 Kbps	0 bps	0	19,202	0
cv_udp-2.2-3.wlan8--1.0.25-B	0 bps	592 bps	19,202	19,202	1,998 96.759
cv_udp-2.2-3.wlan13--1.0.26-A	19,704 Kbps	0 bps	0	6,555	0
cv_udp-2.2-3.wlan13--1.0.26-B	0 bps	394 bps	6,555	6,555	507 73.984
cv_udp-2.2-3.wlan18--1.0.27-A	119,709 Kbps	0 bps	0	0	0
cv_udp-2.2-3.wlan18--1.0.27-B	0 bps	0 bps	0	0	100
cv_udp-2.2-3.wlan4--1.0.28-A	8.897 Kbps	0 bps	0	48,535	0
cv_udp-2.2-3.wlan4--1.0.28-B	0 bps	2,756 Kbps	48,535	48,535	2,746 72
cv_udp-2.2-3.wlan9--1.0.29-A	11,035 Kbps	0 bps	0	20,452	0
cv_udp-2.2-3.wlan9--1.0.29-B	0 bps	197 bps	20,452	20,452	2,812 95.455
cv_udp-2.2-3.wlan14--1.0.30-A	91,239 Kbps	0 bps	0	11,653	0
cv_udp-2.2-3.wlan14--1.0.30-B	0 bps	4.72 Kbps	11,653	11,653	1,077 86.17
cv_udp-2.2-3.wlan19--1.0.31-A	28.15 Kbps	0 bps	0	0	0
cv_udp-2.2-3.wlan19--1.0.31-B	0 bps	0 bps	0	0	100

AX 5Ghz Throughput (goodput) for each station.

5Ghz Throughput
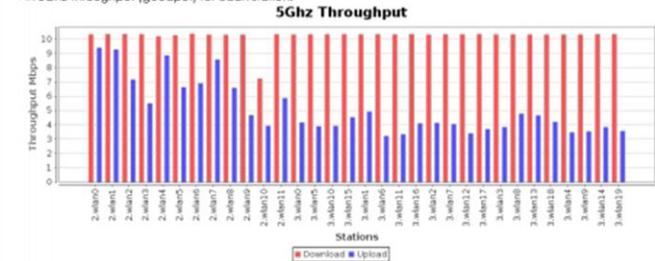
Max-Cx-Test: Snapshot AX 5Ghz Download

Port	Tx-Bps 1m	RxBps 1m	Tx-Fail %	Tx-Link-Rate	Rx-Link-Rate	Mode	Channel	Last CX-Time(ms)	RSSI (dBm)	AP	IP	MAC
1.2.16 wlan0	25 bps	10.625 Mbps		245 Mbps	960.7 Mbps	802.11an-AX	36	251	-37	3C:7C:3F:55:4D:64	192.168.50.74	d8:f8:83:35:db:e9
1.2.17 wlan1	29 bps	10.641 Mbps		245 Mbps	540.3 Mbps	802.11an-AX	36	105	-36	3C:7C:3F:55:4D:64	192.168.50.186	d8:f8:83:35:ba:bf
1.2.18 wlan2	39 bps	10.65 Mbps		245 Mbps	1.201 Gbps	802.11an-AX	36	105	-37	3C:7C:3F:55:4D:64	192.168.50.25	d8:f8:83:36:54:f7
1.2.19 wlan3	29 bps	10.658 Mbps		245 Mbps	864.8 Mbps	802.11an-AX	36	306	-38	3C:7C:3F:55:4D:64	192.168.50.131	d8:f8:83:36:6b:d6
1.2.20 wlan4	39 bps	10.613 Mbps		245 Mbps	313.4 Mbps	802.11an-AX	36	419	-47	3C:7C:3F:55:4D:64	192.168.50.26	a4:6b:b6:3d:61:4c
1.2.21 wlan5	29 bps	10.641 Mbps		245 Mbps	480.3 Mbps	802.11an-AX	36	478	-47	3C:7C:3F:55:4D:64	192.168.50.211	e8:14:08:21:96:84
1.2.22 wlan6	33 bps	10.676 Mbps		245 Mbps	1.201 Gbps	802.11an-AX	36	594	-48	3C:7C:3F:55:4D:64	192.168.50.188	a4:6b:b6:3d:d5:ec
1.2.23	29	10.638		245	960.7	802.11an-						

TR-398 BOM Options

Tests	BOM1	BOM2	BOM3
6.1.1 Receiver Sensitivity Test (11ac only)	✓	✓	
6.2.1 Maximum Connection Test	✓		
6.2.2 Maximum Throughput Test	✓	✓	✓
6.2.3 Airtime Fairness Test	✓	✓	✓
6.2.4 Dual-band Throughput Test	✓	✓	✓
6.2.5 Bidirectional Throughput Test	✓	✓	✓
6.3.1 Range Versus Rate Test	✓	✓	✓
6.3.2 Spatial consistency test	✓	✓	
6.3.3 802.11ax Peak Performance Test	✓		✓
6.4.1 Multiple STAs Performance Test	✓	✓	✓
6.4.2 Multiple Association/Disassociation Stability Test	✓	✓	✓
6.4.3 Downlink MU-MIMO Performance Test	✓	✓	✓
6.5.1 Long Term Stability Test	✓	✓	✓
6.5.2 AP Coexistence Test	✓	✓	✓
6.5.3 Automatic Channel Selection Test	✓	✓	✓

	Function	Testbed Components	BOM1	BOM2	BOM3
Hardware	Station Emulation/Traffic Generation/Test Automation	LANforge : CT-523c-3ac2-db	1 unit	1 unit	1 unit
		LANforge : CT-523c-12axe-10GE	1 unit	1 unit	1 unit
		LANforge : CT-523c-20axe	1 unit	X	X
	RF Isolation	CT820a Medium Chambers	2 units	2 units	2 units
		CT840a Large Chamber with Turntable	1 unit	1 unit	X
	Distance Emulation	CT714 Programmable Attenuators	4 units	4 units	4 units
	RF Connections	4x1 Splitters	6 units	6 units	6 units
		2x1 Splitters	12 unit	12 unit	12 units
		RF Cables	150 units	150 units	150 units
		RF Antennas	100 units	100 units	100 units
Software	Traffic Generation	SW1001m 1GE 1000 Traffic Stream Licenses	3 units	2 units	2 units
		SW1100 10GE port licenses	1 unit	1 unit	1 unit
	Station Emulation	SW1001sta virtual station licenses	400 units	400 units	400 units
	Automation Software	SW-398 : TR-398 automation software license	1 unit	1 unit	1 unit
Support/Warranty		1-year hardware and software support	1 unit	1 unit	1 unit

- BOM1: Full TR-398 Issue 2 setup
- BOM2: BOM1 without 3rd LANforge unit with 20 AX radios.
- BOM3: BOM2 without big chamber and turntable

6.1.1 Receiver Sensitivity Test

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

❑ The Candela implementation for this test supports only AC.
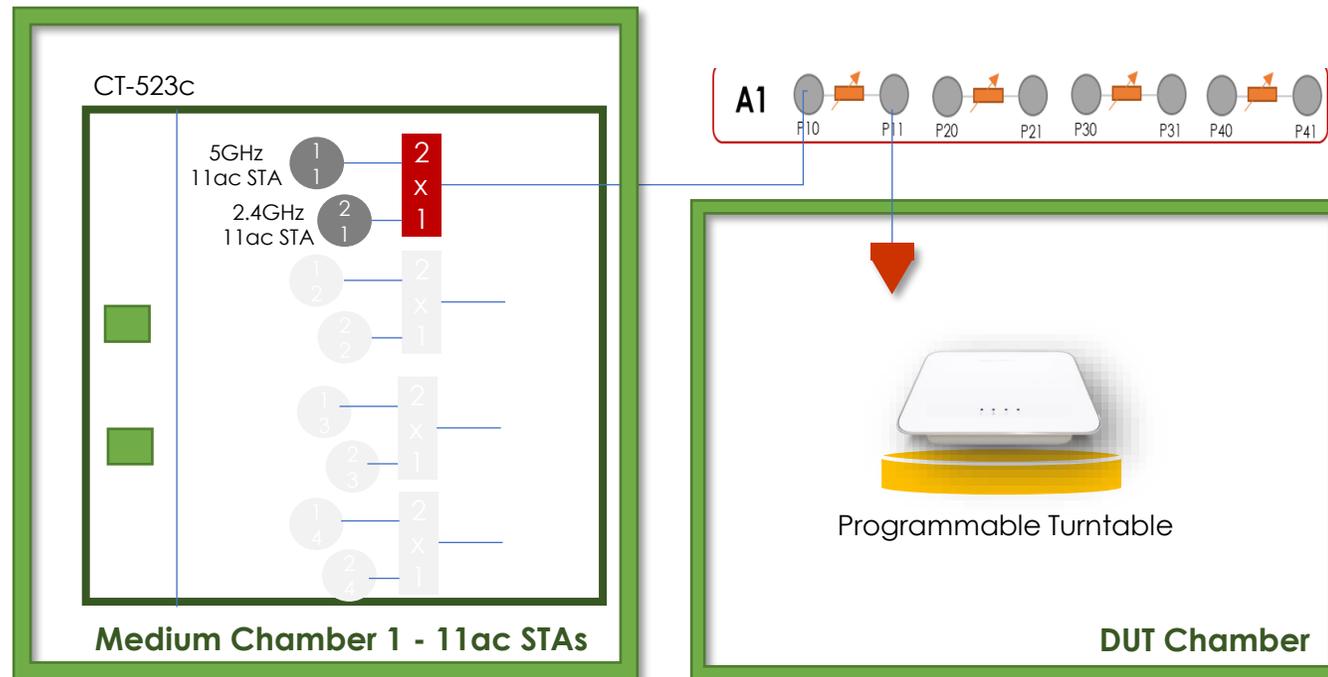
Test Procedure

1. Set the rotation angle to 0 degree.
2. Configure the STA to use the MCS rates.
3. Configure the Traffic Generator to use the test data rate for the configured MCS rate.
4. Allow STA to associate with the DUT.
5. Configure the attenuator(s) to 0 dB.
6. Enable packet generation from the STA to the DUT for 20 seconds.
7. Record packet error rate (PER).
8. Increase the attenuator by 1 dB and repeat steps 6-8 until the PER is greater than 10%. Record the final attenuation value as the approximate receiver sensitivity.
9. Increase the rotation angle by 45 degrees. Repeat Step 5 through 8 until the DUT has been rotated by 360 degrees. Calculate the average receiver sensitivity.
10. Repeat steps for the below configuration as well.

Operating Modes

a) 802.11n
b) 802.11ac
c) 802.11ax over 2.4 GHz
d) 802.11ax over 5 GHz

Pass/Fail Criteria

a) 802.11n

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

b) 802.11ac

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

c) 802.11ax over 2.4Ghz

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

d) 802.11ax over 5Ghz

Test Index	MCS index	Modulation	Approximate Receiver Sensitivity(dB) Required (Nss=1)
3	0	BPSK	46
4	11	1024-QAM	21

6.2.1 Maximum Connection Test

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

Test Procedure

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

Pass/Fail Criteria

Wi-Fi Configuration	Downlink Throughput (Mbps)	Uplink Throughput (Mbps)
Config 1 :For 32 STA -11n - 64Mbps	63.36	63.36
Config 2 :For 32 STA – 11ac – 256Mbps	253.44	253.44
Config 3 :For 32 STA -11ax – 2.4Ghz -96 Mbps	95.04	95.04
Config 4 :For 32 STA – 11ax -5Ghz – 320 Mbps	316.80	316.80

6.2.1 Wiring Diagram

Medium Chamber 1 - 11ac STAs

CT-523c

32 -11 n/ac 2x2 MIMO 2.4/5GHz STAs

DUT Chamber

32 -11ax 2x2 MIMO 2.4/5GHz STAs

CT-523c – 12 11ax STAs

CT-523c – 20 11ax STAs

Medium Chamber 2 - 11ax STAs
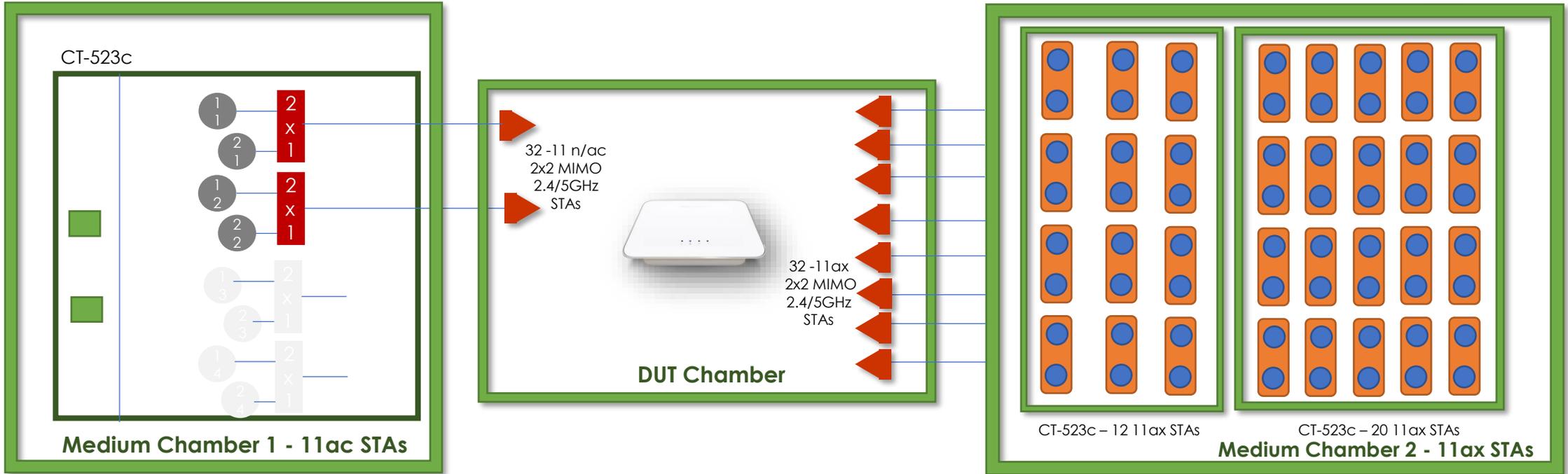
Operating Modes

a) 802.11n
b) 802.11ac
c) 802.11ax over 2.4 GHz
d) 802.11ax over 5 GHz

6.2.2 Maximum Throughput Test

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

Test Procedure

1. Configure the working mode of DUT to 802.11n with default configuration.
2. Establish the LAN connection and allow STA to associate with the DUT.
3. Measure the downlink TCP throughput to the STA, using a test time of 120 seconds.
4. Measure the uplink TCP throughput to the STA, using a test time of 120 seconds.
5. Set the working mode of DUT to 802.11ac and repeat steps 3-4 for bandwidth 80MHz.
6. Set the working mode of DUT to 802.11ax over 2.4 GHz and repeat steps 3-4.
7. Set the working mode of DUT to 802.11ax over 5 GHz and repeat steps 3-4.

Pass/Fail Criteria

Wi-Fi Configuration (DUT) NSS-2	Wi-Fi Configuration(STA), NSS-2	BW	DL Throughput (Mbps) (400ns)	UL Throughput (Mbps) (400ns)	DL Throughput (Mbps)GI-800ns	UL Throughput (Mbps)GI-800ns
802.11n	802.11n (NSS-2)	20	100	100	90	90
802.11ac	802.11ac (NSS-2)	80	560	560	504	504
802.11ax (2.4Ghz)	802.11ax (2.4Ghz)	20	N/A	N/A	200	200
802.11ax (5 Ghz)	802.11ax (5 Ghz)	80	N/A	N/A	720	720

6.2.2 Wiring Diagram

CT-523c

1-11 n/ac
2x2 MIMO
2.4/5GHz
STAs

1-11ax
2x2 MIMO
2.4/5GHz
STAs

Medium Chamber 1 - 11ac STAs

DUT Chamber

CT-523c – 12 11ax STAs

CT-523c – 20 11ax STAs

Medium Chamber 2 - 11ax STAs
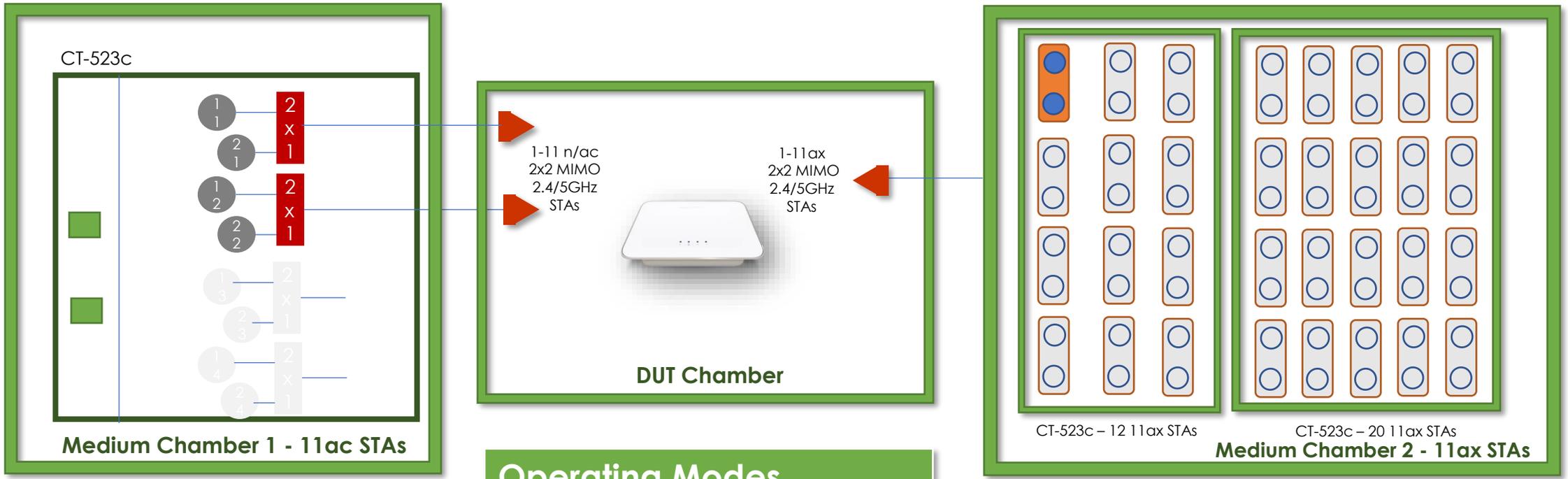
Operating Modes

a) 802.11n
b) 802.11ac
c) 802.11ax over 2.4 GHz
d) 802.11ax over 5 GHz

6.2.3 Airtime Fairness test

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

Test Procedure

1. Establish the setup using default configuration for the 802.11n operating mode.
2. Associate STA1 and STA2 with DUT. Establish the LAN connection and wait for 10 seconds.
3. Measure the downlink TCP throughput to each STA1 and STA2, using a test time of 120 seconds. Record this as STA1 _throughput_1 and STA2 _throughput_1.
4. Move STA2 to a medium distance to the DUT (equivalent to 38 dB@2.4GHz and 25 dB @5GHz attenuation between DUT and STA2). Wait for 10 seconds.
5. Measure the downlink TCP throughput to STA 1 and STA2, using a test time of 120 seconds. Record this as STA1 _throughput_2 and STA2 _throughput_2.
6. Disassociate STA2 with the DUT. Replace STA 2 by STA 3 and remove the attenuation. STA3 is configured to support only a 2.4 GHz connection. Establish the Wi-Fi connection between STA3 and DUT and wait for 10 seconds.
7. Measure the downlink TCP throughput to STA 1 and STA3, using a test time of 120 seconds. Record this as STA1_throughput_3 and STA3 _throughput_3.
8. Replace STA3 with a STA that uses only 802.11a. Set the DUT to operating mode of 802.11ac. Repeat steps 2 to 7.
9. Replace STA3 with a STA that uses only 802.11n. Set the DUT to operating mode of 802.11ax 2.4 GHz. Repeat steps 2 to 7.
10. Replace STA3 with a STA that uses only 802.11ac. Set the DUT to operating mode 802.11ax 5 GHz. Repeat steps 2 to 7.

6.2.3 Wiring Diagram
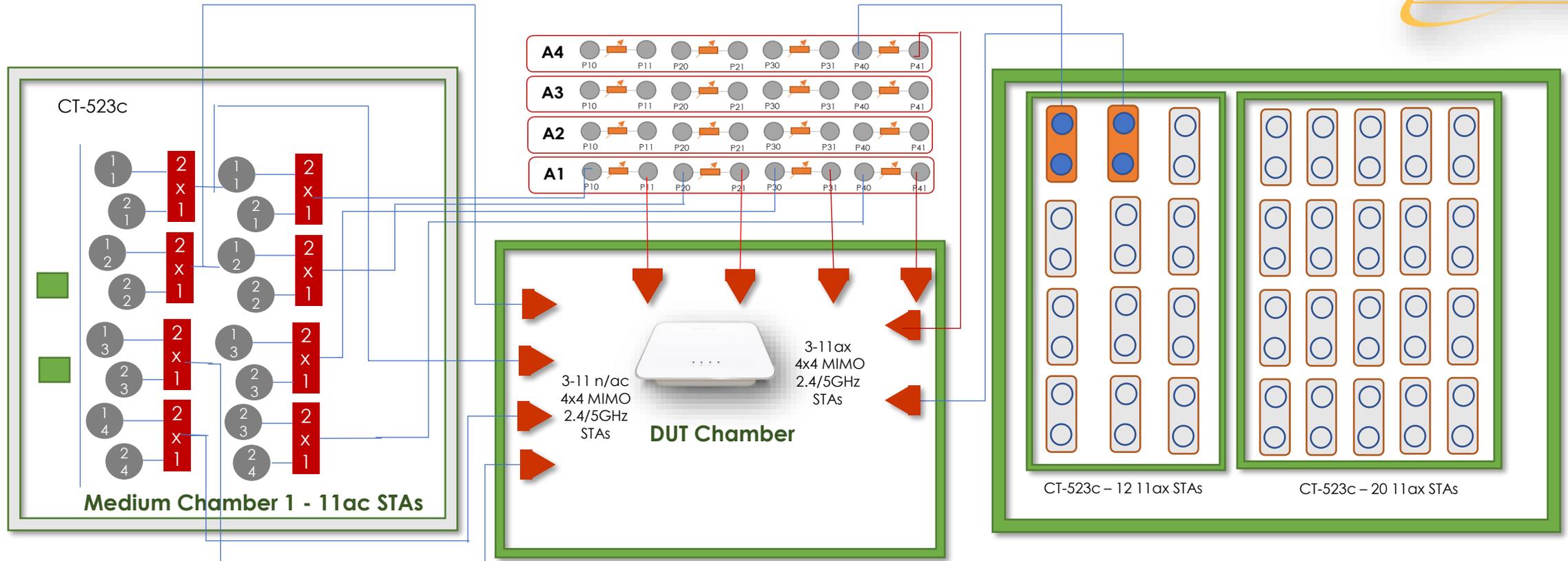
Pass/Fail Criteria

1. For the test in 802.11n 2.4 GHz frequency band:
   1. STA1_throughput_1 SHALL be within (1±5%)*Mean(STA2_throughput_1, STA1_throughput_1).
   2. STA2_throughput_1 SHALL be within (1±5%)*Mean(STA2_throughput_1, STA1_throughput_1).
   3. STA1_throughput_2 SHALL be within (1±15%)*Mean(STA2_throughput_1, STA1_throughput_1).
   4. STA1_throughput_3 SHALL be within (1±15%)*Mean(STA2_throughput_1, STA1_throughput_1).
2. For the test in 802.11n 2.4 GHz frequency band:
   1. The summation of STA1_throughput_1 and STA2_throughput_1 SHALL be larger than 90 Mbps.
   2. The summation of STA1_throughput_2 and STA2_throughput_2 SHALL be larger than 80 Mbps.
   3. The summation of STA1_throughput_3 and STA3_throughput_3 SHALL be larger than 60 Mbps.

6.2.4 Dual Band Throughput Test

❑ The purpose of these test is to detect cross band interference of the DUT's transmitter on the receiver. The weak link is needed to ensure DUT, and STA are transmitting at the highest power and causing the most potential interference when the receiver is more susceptible to noise (low SNR).
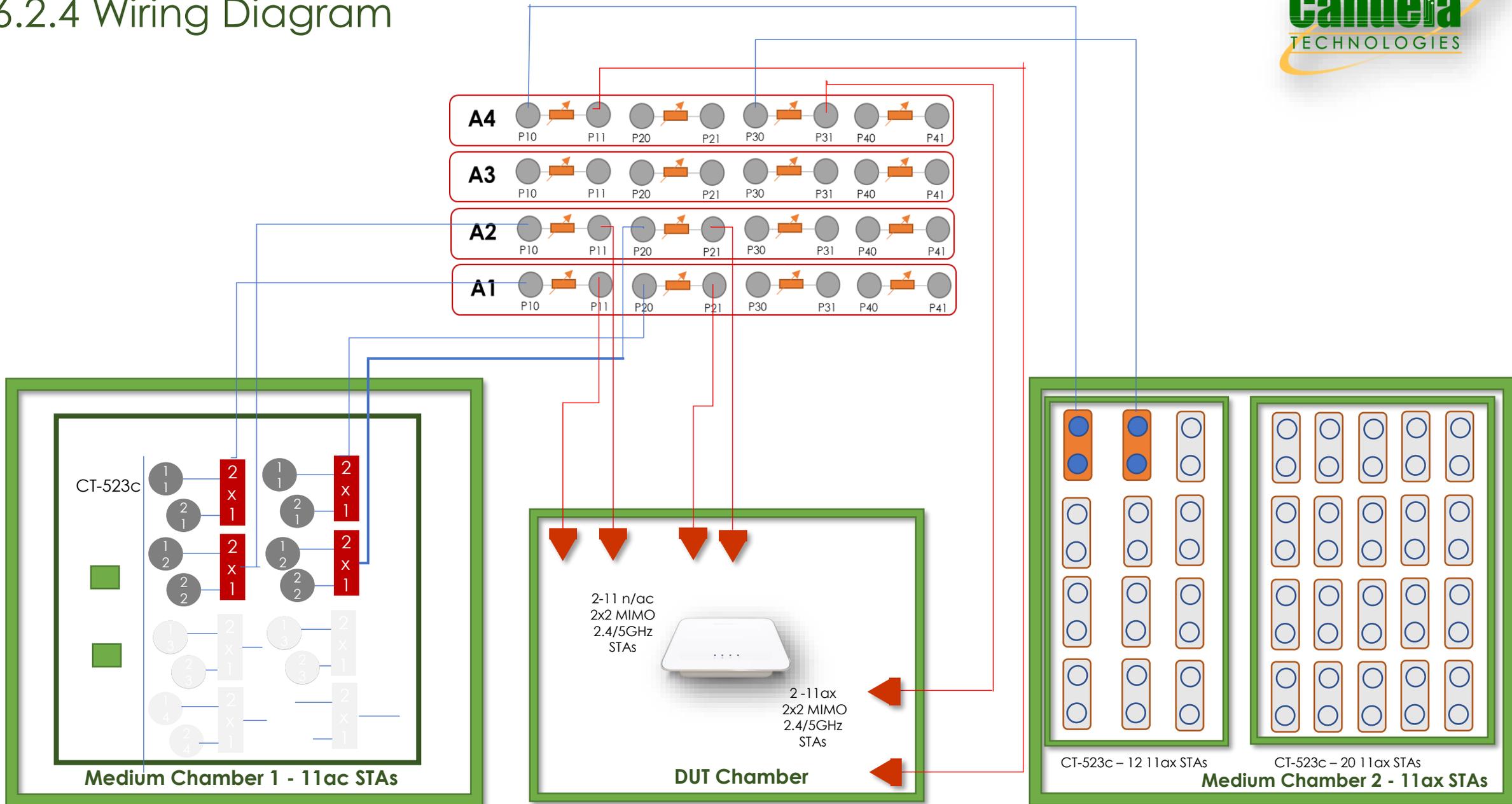
Test Procedure

1. Configure the working mode of DUT to enable both 802.11n and 802.11ac with the default configuration.
2. Establish the LAN connection and allow all STA to associate with the DUT.
3. Simultaneously measure the downlink TCP throughput to all STA, using a test time of 120 seconds.
4. Simultaneously measure the uplink TCP throughput to all STA, using a test time of 120 seconds
5. Simultaneously measure the downlink TCP throughput to the 802.11n STA and the uplink TCP throughput to the 802.11ac STA.
6. Simultaneously measure the uplink TCP throughput to the 802.11n STA and the downlink TCP throughput to the 802.11ac STA.
7. Repeat steps 1 through 6 with the attenuators set to 32 dB for 2.4 GHz STA and 25 dB for 5 GHz STA.
8. Repeat steps 1 through 6 with the attenuators set to 42 dB for 2.4 GHz STA and 35 dB for 5 GHz STA.

Pass/Fail Criteria

Attenuation (dB)	2.4 Ghz -Downlink	2.4 Ghz - Uplink	5 Ghz - Downlink	5 Ghz - Uplink
10 (n/ac)	100	N/A	500	N/A
25/32 (n/ac)	N/A	85	N/A	380
35/42 (n/ac)	45	N/A	N/A	175
10 (ax)	195	N/A	700	N/A
25/32 (ax)	N/A	130	400	N/A
35/42 (ax)	75	N/A	N/A	250

6.2.4 Wiring Diagram

6.2.5 Bidirectional Throughput test

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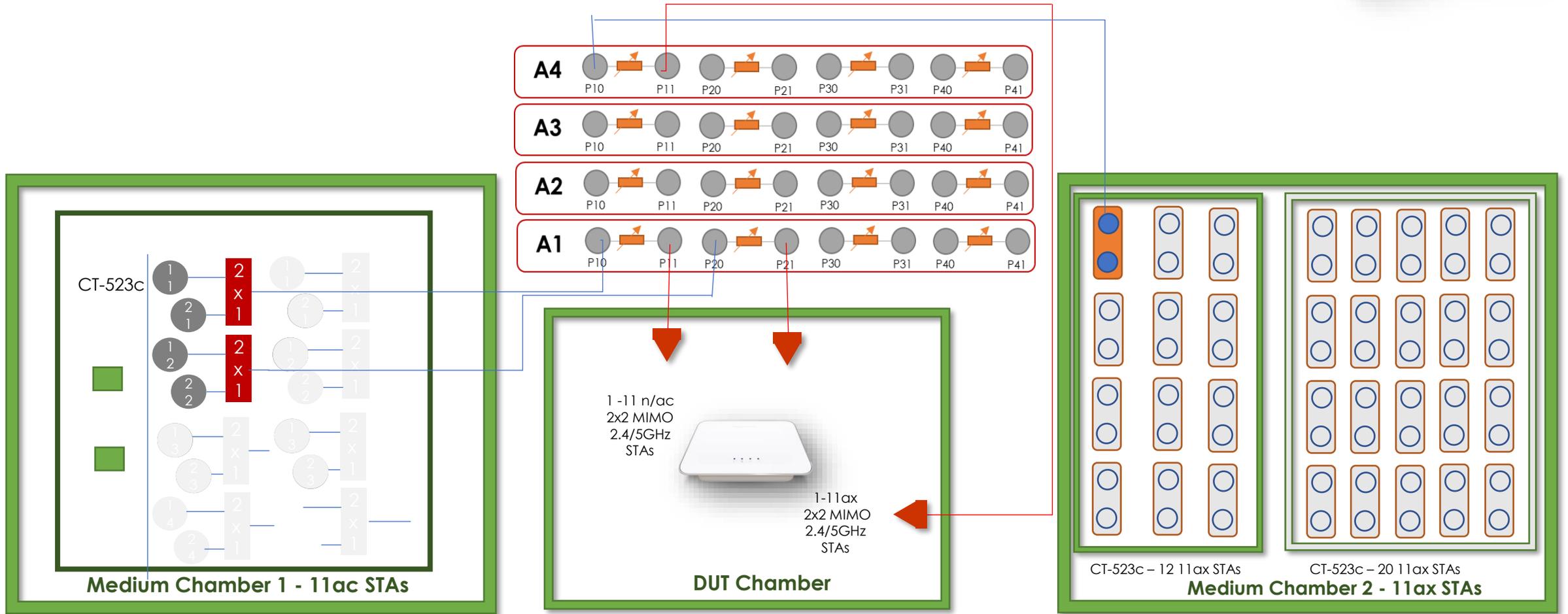
Test Procedure

1. Establish the LAN connection and allow the STA to associate with the DUT.
2. Measure the achievable downlink TCP throughput, using a test time of 120 seconds. Record this value as Throughput_Max_DL.
3. Measure the achievable uplink TCP throughput, using a test time of 120 seconds. Record this value as Throughput_Max_UL.
4. Configure bidirectional UDP traffic streams to use an downlink data rate set to 45% of Throughput_Max_DL and an uplink data rate of 45% of Throughput_Max_UL. Record these values as Throughput_DL and Throughput_UL respectively.
5. Simultaneously run the bidirectional UDP traffic for 120 seconds, recording the number of packets transmitted, received, and dropped in each direction.
6. Calculate the PACKET_LOSS_RATIO_DL and PACKET_LOSS_RATIO_UL as the number of lost packets divided by the total number of packets transmitted.
7. Repeat steps 1 through 6 for attenuator settings 21 dB and 42 dB for 2.4 GHz DUT configurations or 21 dB and 35 dB for 5 GHz DUT configurations.

PASS/FAIL Criteria

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

6.2.5 Wiring Diagram

6.3.1 Rate vs Range Test

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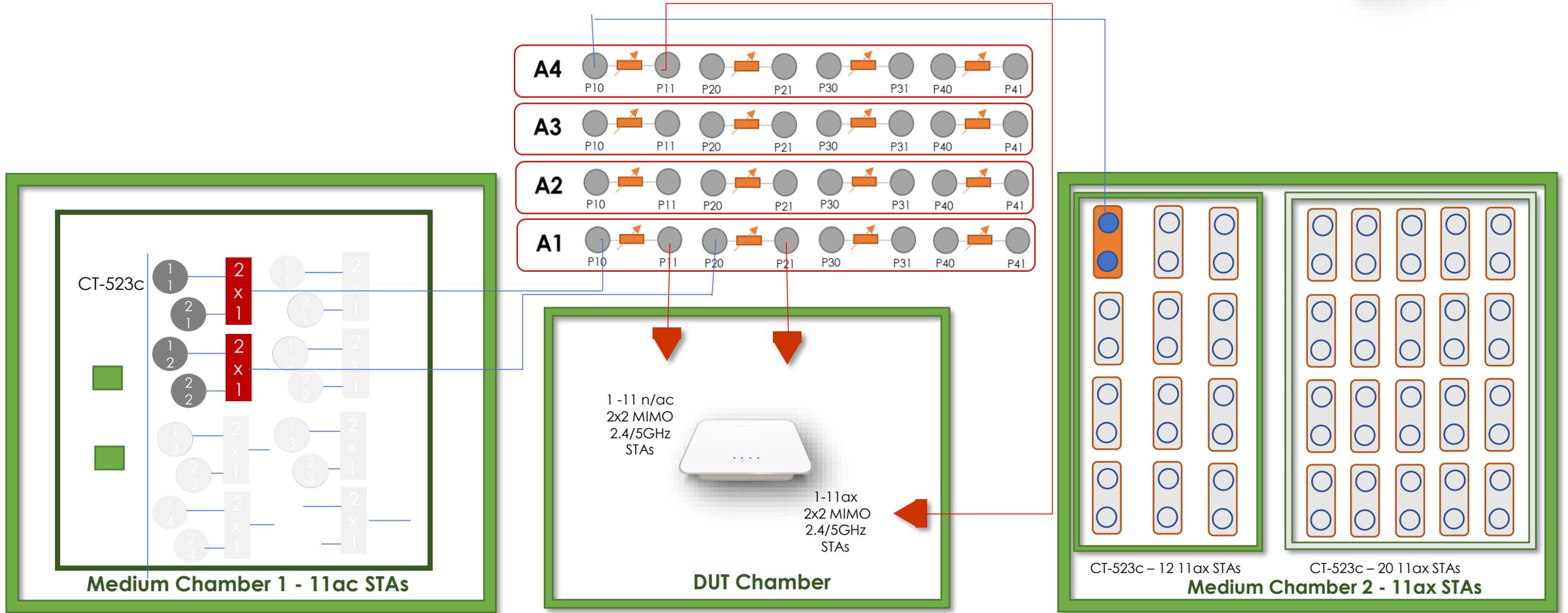
Test Procedure

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

Additional attenuation for test 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 5Ghz	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

6.3.1 Wiring Diagram

Medium Chamber 1 - 11ac STAs

CT-523c

A4 P10 P11 P20 P21 P30 P31 P40 P41

A3 P10 P11 P20 P21 P30 P31 P40 P41

A2 P10 P11 P20 P21 P30 P31 P40 P41

A1 P10 P11 P20 P21 P30 P31 P40 P41

1 -11 n/ac
2x2 MIMO
2.4/5GHz
STAs

1-11ax
2x2 MIMO
2.4/5GHz
STAs

DUT Chamber

CT-523c – 12 11ax STAs   CT-523c – 20 11ax STAs

Medium Chamber 2 - 11ax STAs

6.3.1 Pass/Fail Criteria

2.4Ghz-Attenuation	0	10	21	24	27	30	33	36	39	42	45	48	51	54	57	60	63
N 2.4G-Download(Mbps)	100	100	100	100	100	100	100	95	80	75	50	31	24	17	12	7	4
N 2.4G-Upload(Mbps)	100	100	100	100	100	100	100	95	80	75	50	45	35	25	14	9	8
AX 2.4G-Download(Mbps)	200	200	200	200	200	180	170	150	120	90	85	65	55	30	25	15	10
AX 2.4G-Upload(Mbps)	200	200	200	200	200	180	170	150	120	90	85	65	50	25	20	10	5

| 5Ghz-Attenuation	0	10	21	24	27	30	33	36	39	42	45	48	51	54
AC 5G-Download(Mbps)	560	530	420	400	360	300	220	150	125	100	45	25	5	1
AC 5G-Upload(Mbps)	560	530	420	400	360	300	220	150	125	100	45	25	5	1
AX 5G-Download(Mbps)	720	680	540	515	465	400	350	300	200	175	150	50	7	2
AX 5G-Upload(Mbps)	720	680	540	515	465	400	300	225	175	150	50	25	5	2

6.3.2 Spatial Consistency Test

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

❑ 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.

Test Procedure

1. Configure the working mode of DUT to 802.11n, operating frequency band to 2.4 GHz with default configuration.
2. Establish the LAN connection and allow STA to associate with to the DUT.
3. Measure the downlink TCP throughput to the STA, using a test time of 60 seconds. Wait for 10 seconds. Measure the uplink TCP throughput to the STA, using a test time of 60 seconds.
4. Rotate the DUT platform by 30° and repeat Step 3 until the platform has been rotated by 360°.
5. Increase the attenuation for each RF chain according and reset the position of DUT platform to 0°, until all the attenuation values have been tested. Repeat Step 2-5.
6. Set the working mode of DUT to 802.11ac with a bandwidth of 80 MHz and operating frequency to 5 GHz, reset the position of DUT platform to 0°. Repeat Step 2-5.
7. Set the working mode of DUT to 802.11ax over 2.4 GHz with a bandwidth of 20 MHz and reset the position of DUT platform to 0°. Repeat Step 2-5.
8. Set the working mode of DUT to 802.11ax over 5 GHz with a bandwidth of 80 MHz and reset the position of DUT platform to 0°. Repeat Step 2-5.

6.3.2 Wiring Diagram
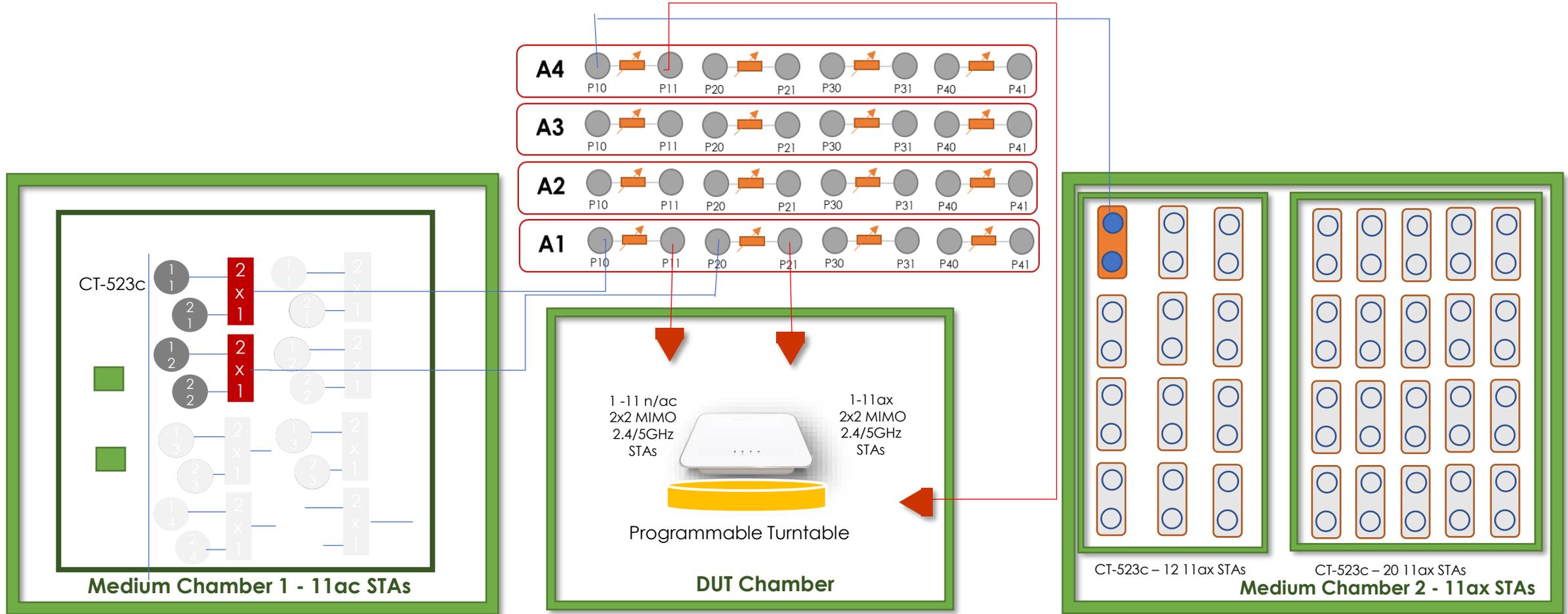
6.3.2 Pass/Fail Criteria

Wi-Fi Configuration (DUT)	Wi-Fi Configuration (STA)	Bandwidth	Throughput_S (Mbps)		Throughput_M (Mbps)		Throughput_L (Mbps)	
			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	400	400	300	300
802.11ax (2.4Ghz NSS-2)	802.11ax (2.4Ghz 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

For each rotation, the variation in rates must be within a specified range. 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.

1. For 2.4Ghz, the range is 30%
2. For 5Ghz, the range is 40%
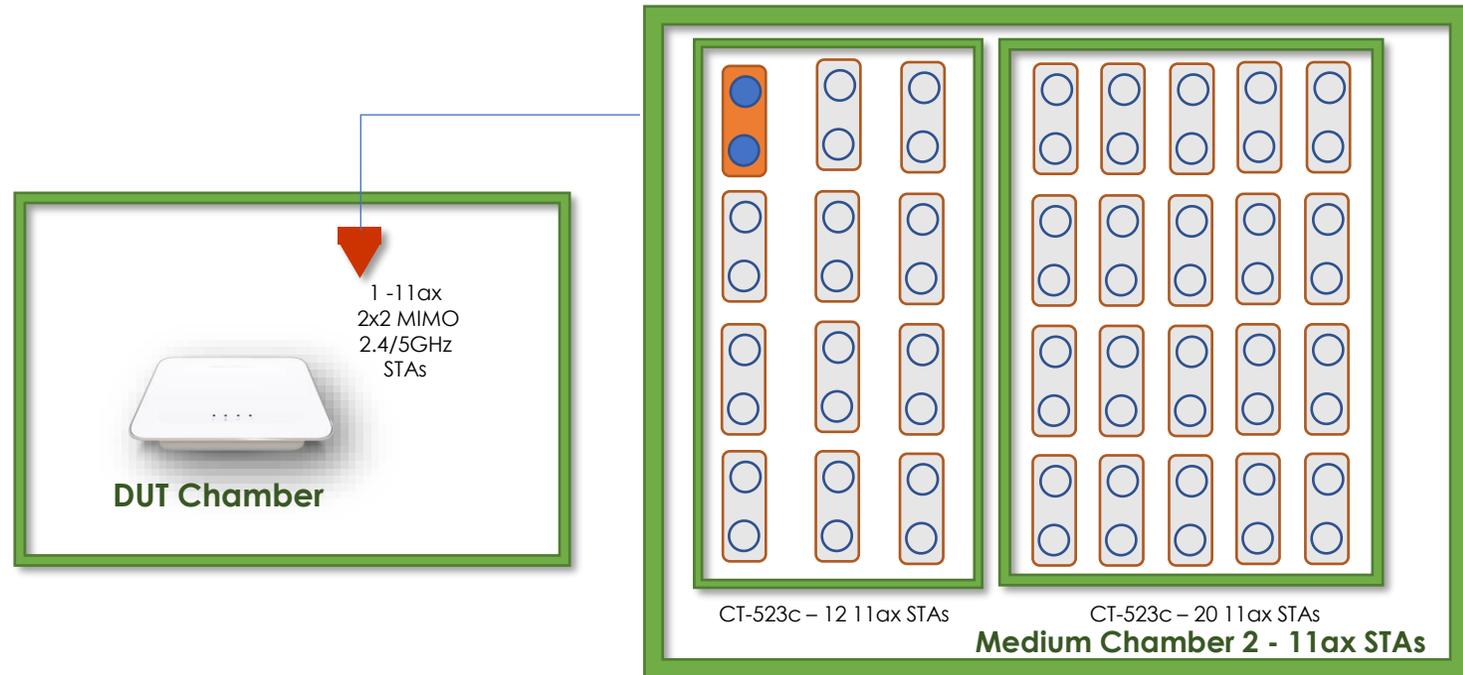
6.3.3 802.11ax Peak Performance Test

❑ This test case examines the maximum performance expected from a DUT supporting 802.11ax

Test Procedure

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

Pass/Fail Criteria

Wi-Fi Configuration	Downlink Throughput (Mbps)	Uplink Throughput (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

1 -11ax
2x2 MIMO
2.4/5GHz
STAs

DUT Chamber

CT-523c – 12 11ax STAs

CT-523c – 20 11ax STAs

Medium Chamber 2 - 11ax STAs

6.4.1 Multiple STAs Performance Test

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

Test Procedure

1. Configure the working mode of DUT to 802.11n, operating frequency band to 2.4 GHz with default configuration.
2. Establish the LAN connection and allow STA to associate with to the DUT.
3. Measure the downlink TCP throughput to the STA, using a test time of 60 seconds. Wait for 10 seconds. Measure the uplink TCP throughput to the STA, using a test time of 60 seconds.
4. Rotate the DUT platform by 30° and repeat Step 3 until the platform has been rotated by 360°.
5. Increase the attenuation for each RF chain according and reset the position of DUT platform to 0°, until all the attenuation values have been tested. Repeat Step 2-5.
6. Set the working mode of DUT to 802.11ac with a bandwidth of 80 MHz and operating frequency to 5 GHz, reset the position of DUT platform to 0°. Repeat Step 2-5.
7. Set the working mode of DUT to 802.11ax over 2.4 GHz with a bandwidth of 20 MHz and reset the position of DUT platform to 0°. Repeat Step 2-5.
8. Set the working mode of DUT to 802.11ax over 5 GHz with a bandwidth of 80 MHz and reset the position of DUT platform to 0°. Repeat Step 2-5.

6.4.1 Wiring Diagram
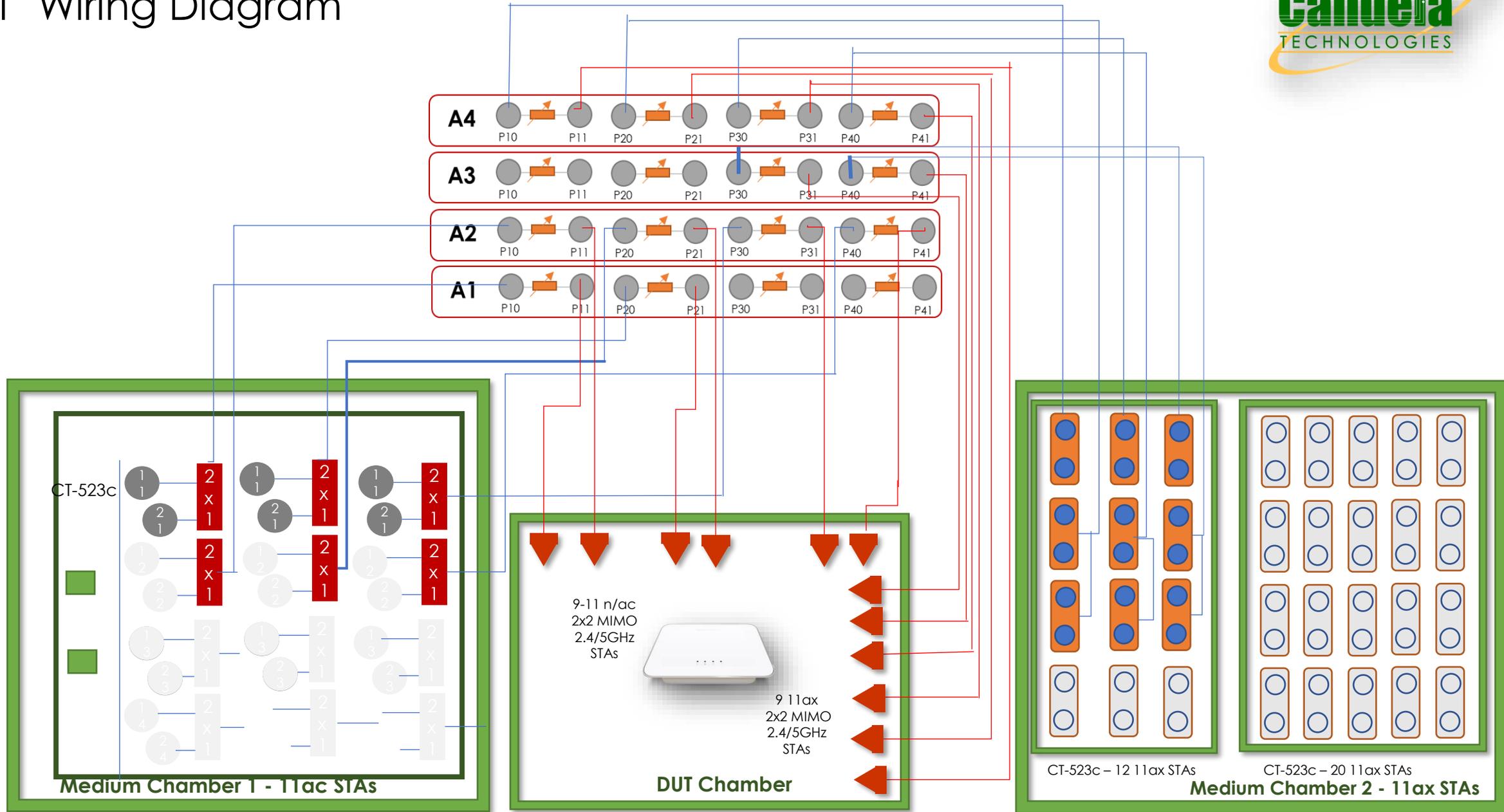
6.4.1 Pass/Fail Criteria

| Wi-Fi Configuration (DUT)	Wi-Fi Configuration (STA)	Bandwidth	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 (2.4Ghz NSS-2)	802.11ax (2.4Ghz NSS-2)	20	140	140	120	120	100	100
802.11ax (5 Ghz, NSS-2)	802.11ax (5 Ghz, NSS-2)	80	680	600	600	250	500	200

6.4.2 Multiple Association/Disassociation Stability Test

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

Test Procedure

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

6.4.2 Wiring Diagram
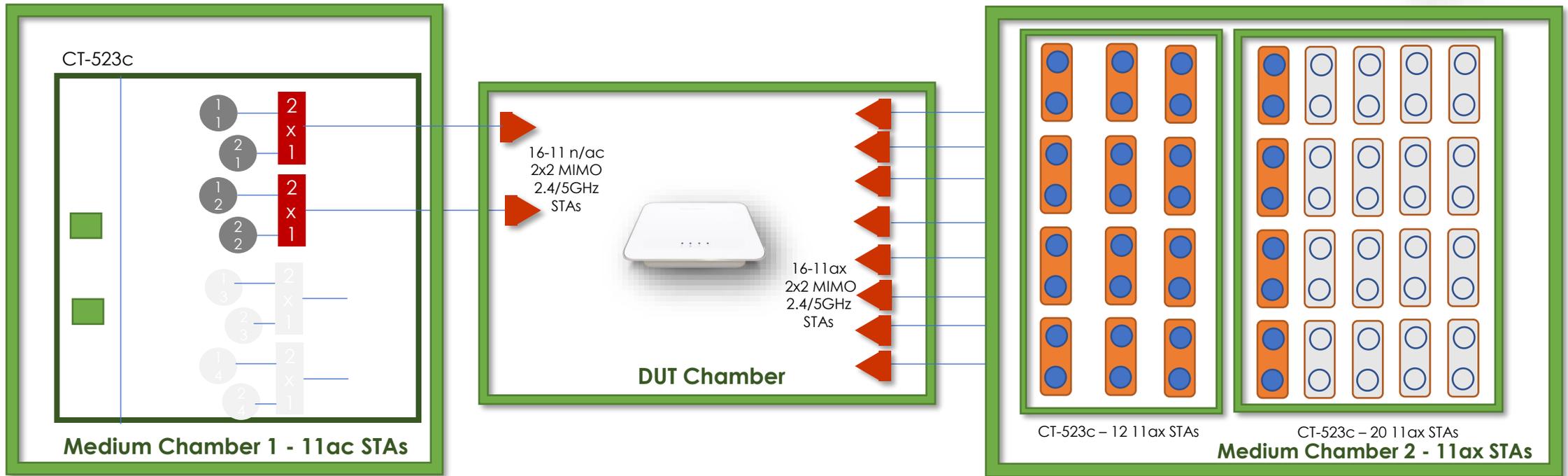
Pass/Fail Criteria

In order to pass the test case, the recorded results SHALL meet the Pass/Fail Criteria, described as following:
a) The disassociation/association does not affect the performance of other peer STAs.
b) UDP traffic rate is at least 99% of the configured rate for each STA.
c) UDP packet loss rate SHALL be less than 0.01%.
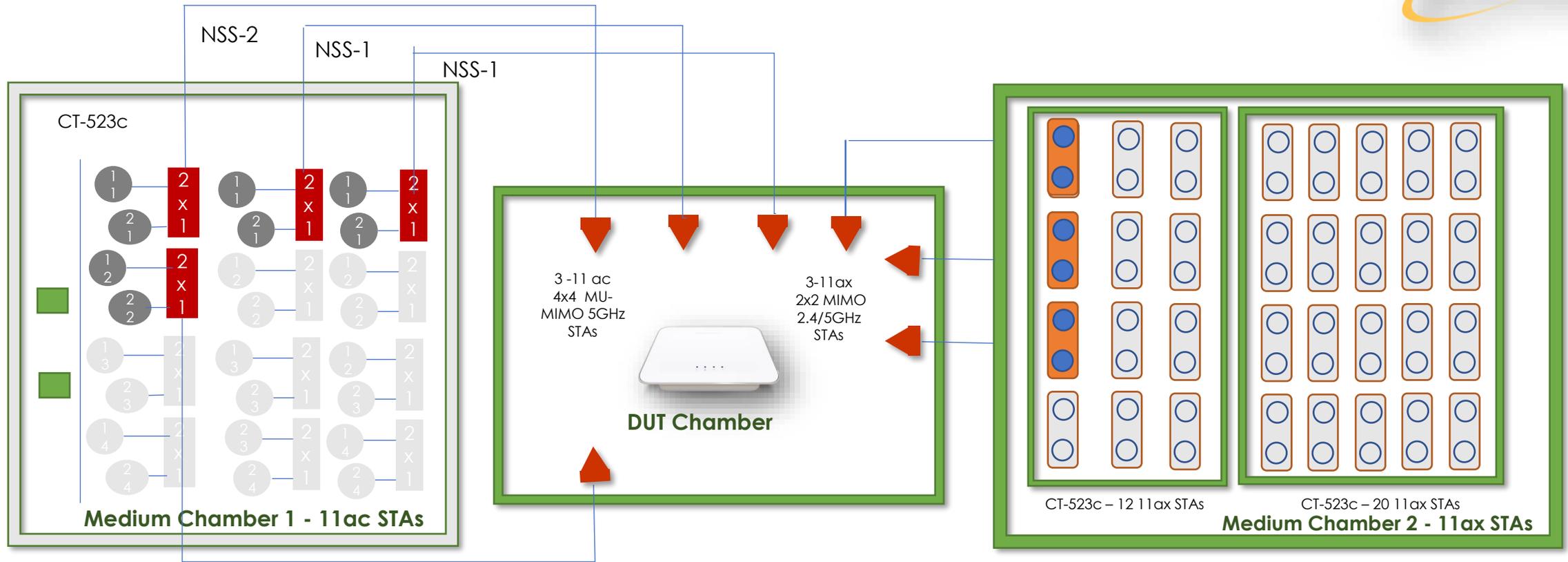
6.4.3 Downlink MU-MIMO Performance Test

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

Test Procedure

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

6.4.3 Wiring Diagram

CT-523c

NSS-2
NSS-1
NSS-1

Medium Chamber 1 - 11ac STAs

3 -11 ac
4x4 MU-MIMO 5GHz
STAs

3-11ax
2x2 MIMO
2.4/5GHz
STAs

DUT Chamber

CT-523c – 12 11ax STAs

CT-523c – 20 11ax STAs

Medium Chamber 2 - 11ax STAs

Pass/Fail Criteria

In order to pass the test case, the recorded results SHALL meet the Pass/Fail Criteria, described as follows:
a) The sum of STA1_throughput_2, STA2_throughput_2, and STA3_throughput_2 SHALL be at least 45%
of the sum of STA1_throughput_1, STA2_throughput_1, and STA3_throughput_1.
b) The sum of STA1_throughput_2, STA2_throughput_2, and STA3_throughput_2 SHALL be greater than
the sum of STA1_throughput_3, STA2_throughput_3, and STA3_throughput_3. This test metrics SHALL only apply to the DUT that supports the configuration
to disable DL MU-MIMO

6.5.1 Long Term Stability test

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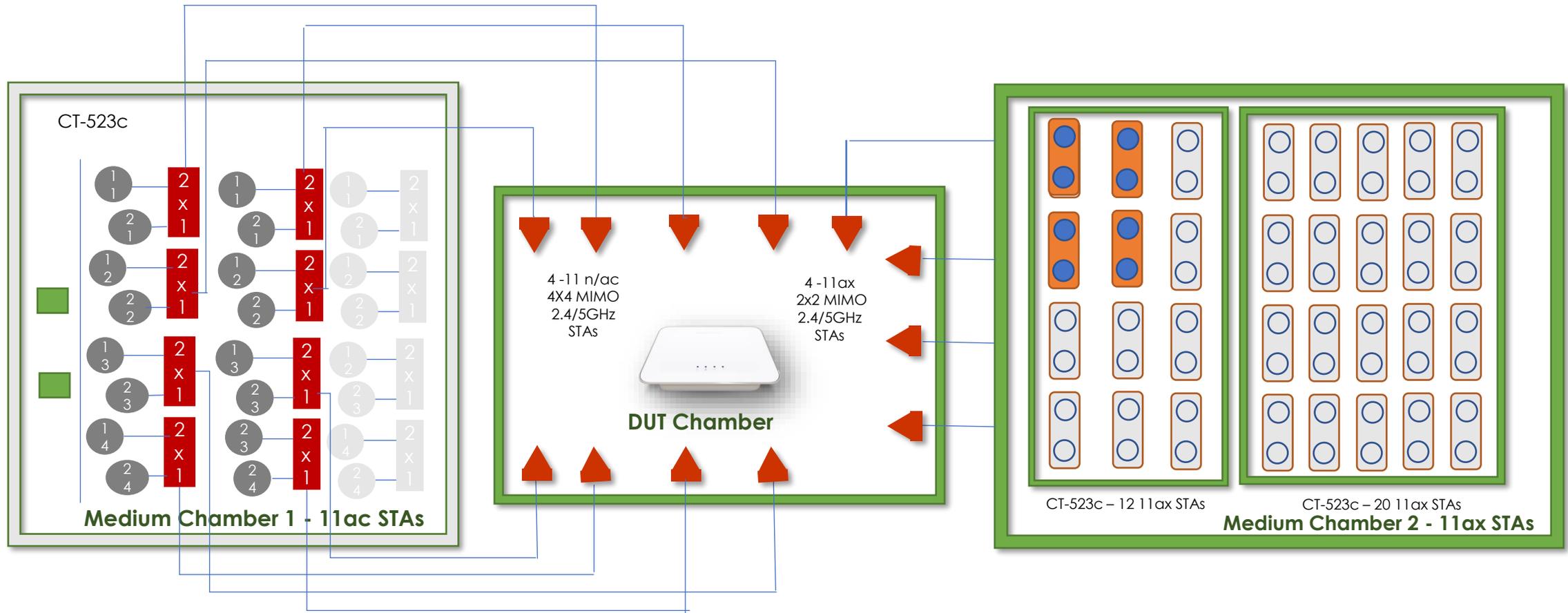
Test Procedure

1. Configure the DUT for the first operating configuration described above.
2. Configure the 2 STAs connecting to the 2.4 GHz band to associate with the DUT.
3. Configure the 2 STAs connecting to the 5 GHz band to associate with the DUT.
4. Wait for 60 seconds for the system to reach a steady state.
5. Configure two downlink UDP throughput measurements to run for 15 minutes each using a bit rate of 50Mbps through one 2.4 GHz STA and one 5 GHz STA. While this throughput measurement is running perform the following actions:
    i. Wait 5 minutes
    ii. Toggle the association state of the second STA in each band (i.e., if the STA is currently associated to the DUT,cause it to disassociate; or if it is disassociated, cause it to associate).
6. Record the number of lost UDP packets for each downlink measurement, recording the measurement as PACKET_LOSS_[24 or 5]_GHZ_INTERVAL_n, where the band is indicated as 2.4 or 5 GHz and n represents the n'th measurement interval. Calculate the PACKET_LOSS_RATIO_[24 or 5]_GHZ_INTERVAL_n as the number of lost packets divided by the total number of packets transmitted.
7. Repeat steps 4 and 5 for a total of 16 measurement intervals (4 hours of testing).
8. Repeat steps 1 through 6 for each DUT configuration.

Pass/Fail Criteria

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

6.5.1 Wiring Diagram

CT-523c

Medium Chamber 1 - 11ac STAs

4 -11 n/ac
4X4 MIMO
2.4/5GHz
STAs

4 -11ax
2x2 MIMO
2.4/5GHz
STAs

DUT Chamber

CT-523c – 12 11ax STAs

CT-523c – 20 11ax STAs

**Medium Chamber 2 - 11ax STAs**

6.5.2 AP Coexistence test

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

Test Procedure

1. Configure the working mode of DUT to 802.11n, operating frequency band to 2.4 GHz with default configuration. Allow peer STA registers the DUT.
2. The channel of alien network SHALL be set to the same channel as DUT.
3. Keep the alien network radios shutdown (not transmitting any signals).
4. Wait for 10 seconds. Measure the downlink TCP throughput to peer STA, using a test time of 120 seconds. Record this measurement as THROUGHPUT_SHORT_DUT.
5. Enable the alien network radios. The alien network SHALL be configured according to Table 35. The alien network will transmit beacon frames according to the default configuration settings.
6. Wait for 10 seconds. Measure the downlink TCP throughput to peer STA, using a test time of 120 seconds. Record this measurement as THROUGHPUT_SHORT_DUT_1.
7. Configure the alien network to utilize 50% of the available "air time". This can be achieved by packet transmission using the alien network of 1500-byte packets at one of the following rates, depending on the configuration used for the alien network and the wireless MSC rate selected by the transmitter: 32 Mbps for 802.11n 20MHz channels with 1 spatial stream, 90 Mbps for 802.11ac 40MHz with 1 spatial stream, 195 Mbps for 802.11ac 80MHz with 1 spatial stream, 65 Mbps for 802.11n 20MHz channels with 2 spatial streams, 180 Mbps for 802.11ac 40MHz with 2 spatial streams, or 390 Mbps for 802.11ac 80MHz with 2 spatial streams.
8. Wait for 10 seconds. Measure the downlink TCP throughput to peer STA, using a test time of 120 seconds. Record this measurement as THROUGHPUT_SHORT_DUT_2.
9. Change the channel configuration of alien AP according to Table 35 until all the configuration has been tested. Repeat Step 8. Stop the packet transmission for alien network.
10. Shut down the radios on the alien network.
11. Repeat steps 2 to 10 for each additional configuration listed in Table 34 above.

6.5.2 Wiring Diagram
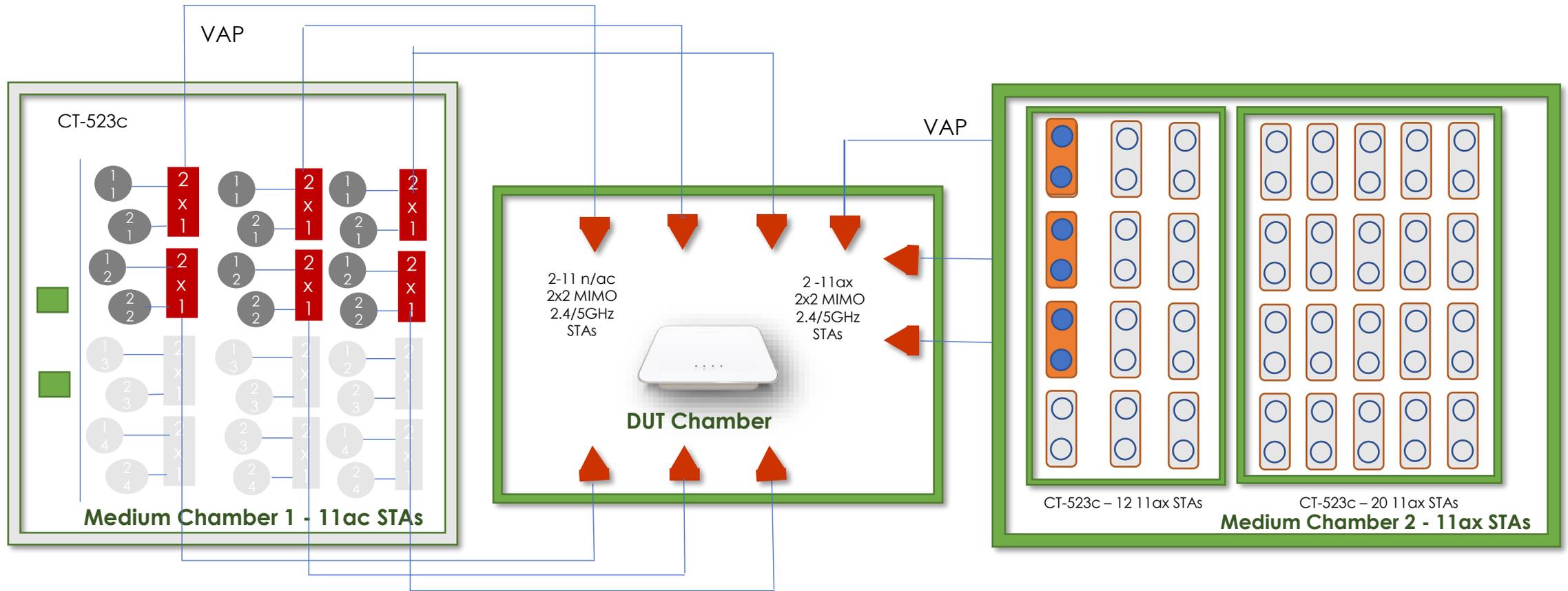
6.5.2 Pass/Fail Criteria

| Wi-Fi Configuration (DUT)	Wi-Fi Configuration (STA)	Bandwidth	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 (2.4Ghz NSS-2)	802.11ax (2.4Ghz NSS-2)	20	-	<5%	<60%	<60%	<5%
802.11ax (5 Ghz, NSS-2)	802.11ax (5 Ghz, NSS-2)	80	-	<5%	<60%	<60%	<5%
Note: Percentage indicates the performance deduction referred to the case with no alien device turned on.							

6.5.3 Automatic Channel Selection test

❑ The test verifies the DUT (AP) will select a Wi-Fi channel that is not presently utilized by other networks and will alter this channel on subsequent reboots, if the environment has changed (i.e. the channels utilized by the adjacent network has changed).

Test Procedure

1. Power off the DUT. Allow the second station to associate to the additional AP.
2. Configure the Ethernet traffic generator to run a continuous TCP throughput measurement, causing the devices to continuously transmit over the Wireless link between the second STA and AP.
3. Power on the DUT and allow the first station to associate with the DUT.
4. Record the channel used by the DUT.
5. Repeat steps 1 through 5, with the additional AP configured to use 2.4 GHz channels 1 and 11.
6. Repeat steps 1 through 5, with the additional AP configured to use 2.4 GHz channel 1 and 40 MHz bandwidth.
7. Repeat steps 1 through 5, using the 5 GHz band, with the additional AP configured to channels 42, 58, 106, and 122. The additional AP should be configured to use a channel bandwidth of 80 MHz.

6.5.3 Wiring Diagram
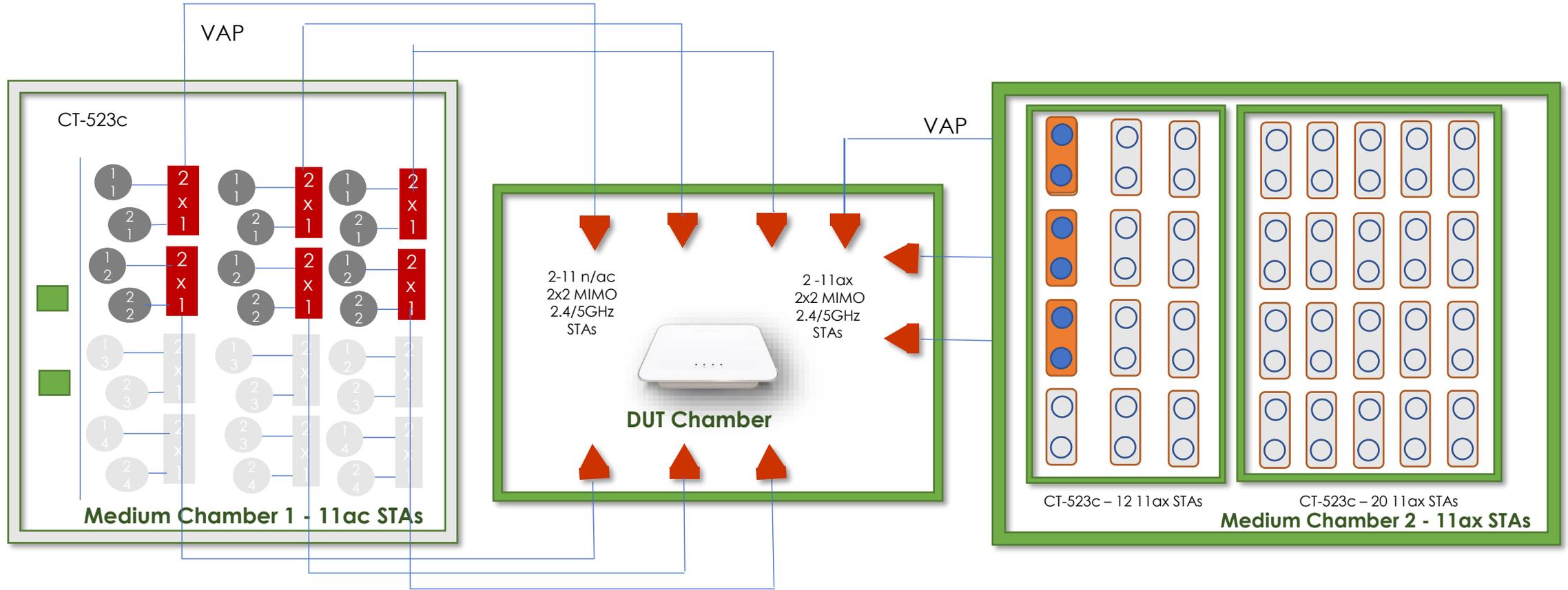
6.5.3 Pass/Fail Criteria

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

I	Additional AP Operating Band and Channel	Channel selected by 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	

📧 sales@candelatech.com

☎ 1-360-380-1618