Candela TECHNOLOGIES

Candela Wi-Fi Router/Access Point Test Report

Version 1.0

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DUT Configuration

Table 1.1

DUT Configuration Details	
Mode	n, ac, ax, be
Band	2.4 GHz, 5 GHz & 6 GHz
Channel	2.4 GHz – 6, 5 GHz – 36 & 6 GHz - 37
Bandwidth	2.4 GHz – 20, 40 MHz 5 GHz – 80, 160 MHz 6 GHz – 160, 320 MHz

Testbed Images

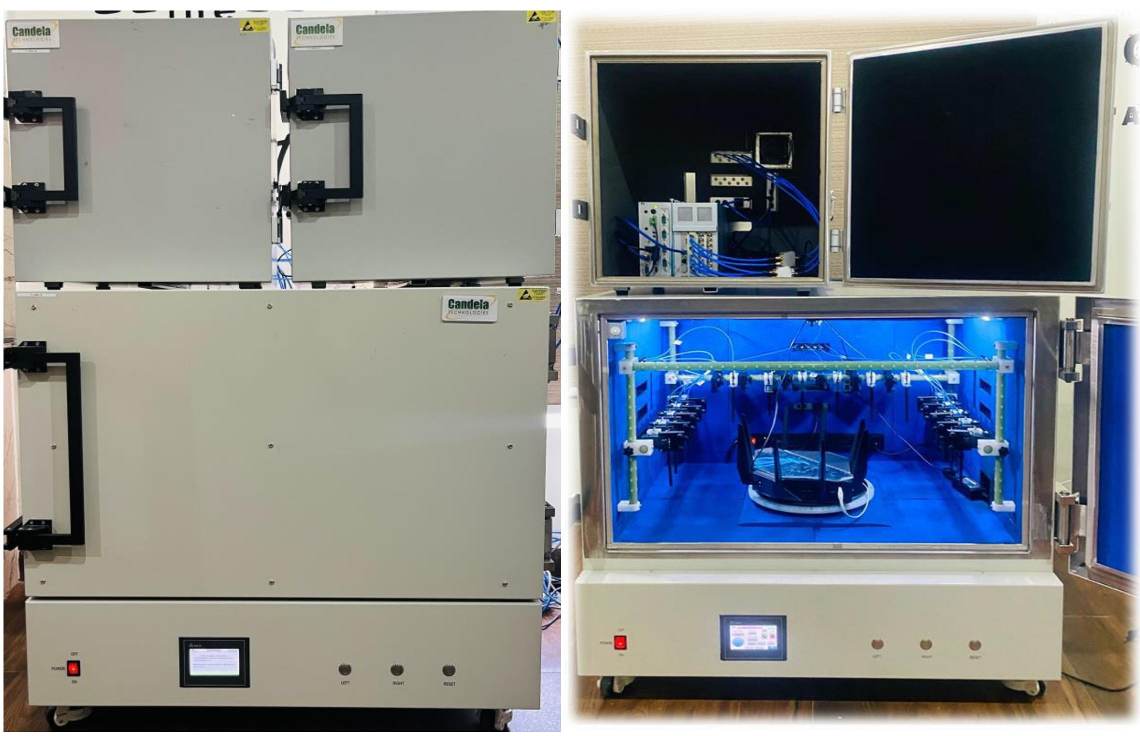


Image 1.1 - TR-398 Testbed Image

Image 1.2 - Standalone Testbed Image

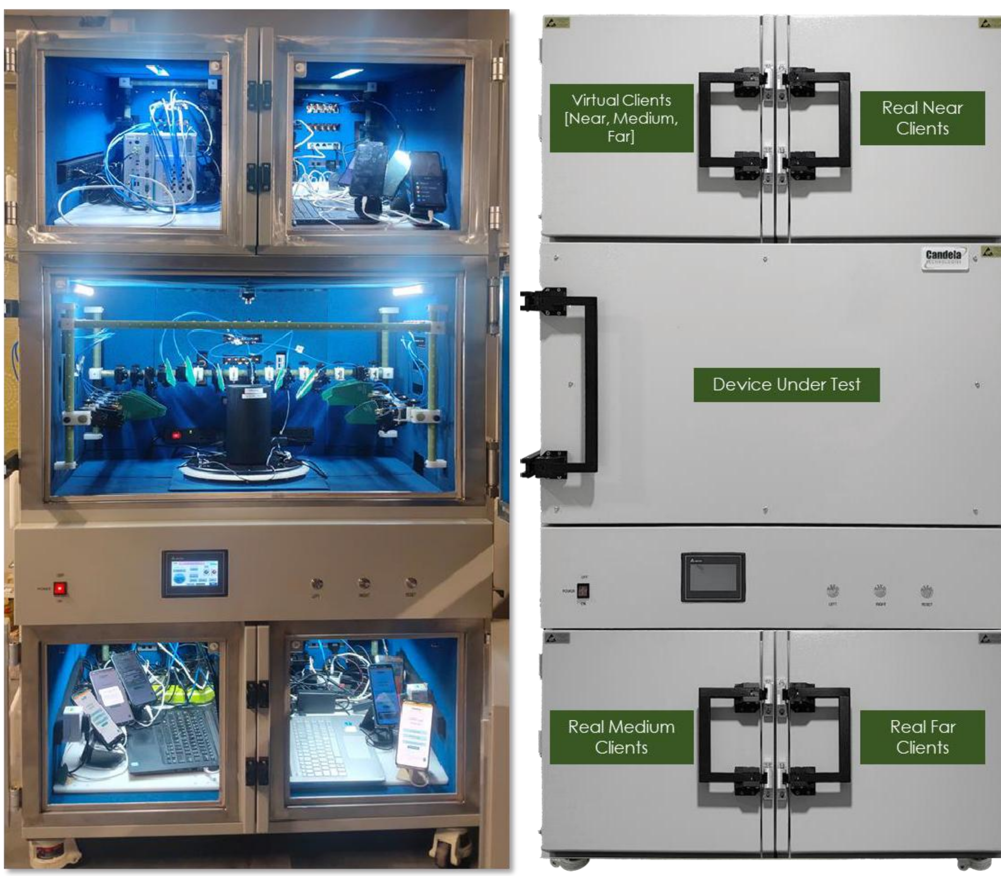


Image 1.3 - Home in a Box Testbed Image

Image 1.4 - DFS Testbed Image

Image 1.5 - Walk-In Chamber Image

Image 1.6 - Real devices in Chamber Image

Image 1.7 - Test house Image

Lab Testing with virtual devices

Basic Test Suite

AP Capabilities

Objective:

The AP Capabilities Test verifies that DUT correctly supports and advertises required Wi-Fi features, including bands, bandwidths, security modes, and other key wireless functions, ensuring correct behavior and consistent capability advertisement across configurations.

Observations:

Band	Standard	MCS Range	Max NSS	Channel Bandwidths	Key PHY Features
2.4 GHz	HT	0–31	2	20,40 MHz	Short GI, LDPC, STBC
2.4 GHz	HE	0–11	2	20,40 MHz	OFDMA, UL/DL MU-MIMO, BSS Coloring, TWT
2.4 GHz	EHT	0–13	2	20,40 MHz	MLO, Preamble Puncturing
5 GHz	HT	0–31	4	20,40 MHz	Short GI, LDPC, STBC
5 GHz	VHT	0–9	4	20,40,80,160 MHz	SU-BF, MU-MIMO, STBC
5 GHz	HE	0–11	4	20,40,80,160 MHz	OFDMA, UL/DL MU-MIMO, BSS Coloring, TWT
5 GHz	EHT	0–13	4	20,40,80,160 MHz	MLO, Preamble Puncturing
6 GHz	HT	0–11	4	20,40 MHz	Short GI, LDPC, STBC
6 GHz	EHT	0–13	4	20,40,80,160,320 MHz	MLO, 320 MHz, Preamble Puncturing

Test Procedure:

1. Configure and power on the DUT with the required band, bandwidth, and features, and start monitor-mode capture on the target channel.
2. Capture over-the-air beacons and probe responses into a PCAP file and filter frames for the DUT SSID/BSSID.
3. Extract advertised capabilities (band, bandwidth, HT/VHT/HE/EHT, MCS/NSS, security, and features).
4. Compare extracted capabilities against the expected DUT configuration.
5. Log results and generate a final pass/fail report.

Pass/Fail Criteria:

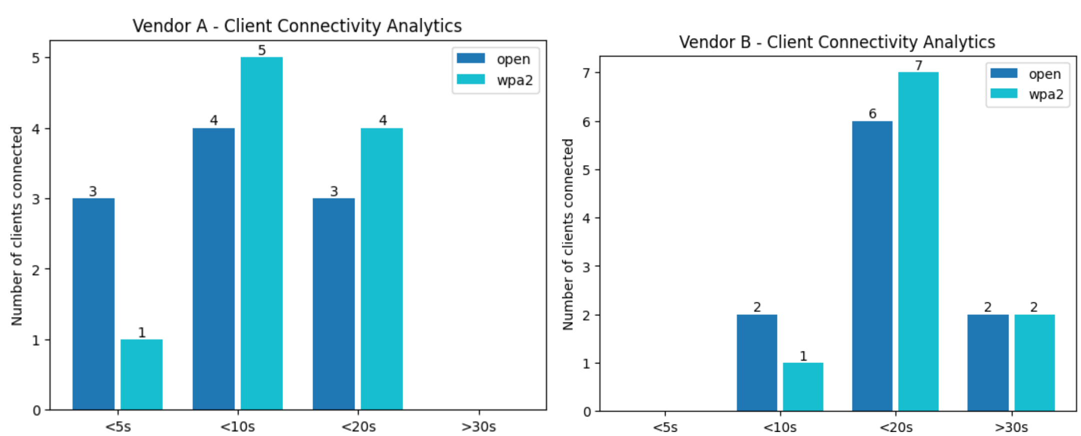
- All advertised capabilities observed in the PCAP (bands, bandwidths, PHY features, MCS/NSS, security, and other IEs) exactly match the expected DUT configuration, else fail.

Client Connectivity with open, WPA2/WPA3 Personal

Objective:

This test evaluates DUT connectivity by associating single and multiple clients using different security modes, measuring total connection time, DHCP time, and 4-way handshake completion to verify efficient handling of multiple client connections.

Observations:



- Most clients for both vendors connected within the <10s to <20s range.
- Vendor A shows faster connectivity, with more clients connecting in under 10 seconds.
- Vendor B has more clients in the <20s and >30s ranges, indicating slower and less consistent association.
- WPA2 connections take slightly longer than open connections for both vendors.
- No major connection failures were observed, but Vendor A provides quicker and more stable connectivity overall.

Test Procedure:

1. Configure the DUT with the required security mode and start packet capture in monitor mode on the target band/channel.
2. Initiate single-client and then multi-client connections while recording timestamps.
3. From the PCAP, measure association time, handshake completion, and DHCP completion.
4. Calculate total connectivity time (first management frame to DHCP ACK) and verify stable IP connectivity.
5. Log per-client results, failures, anomalies, and determine pass/fail based on performance and stability.

Pass/Fail Criteria:

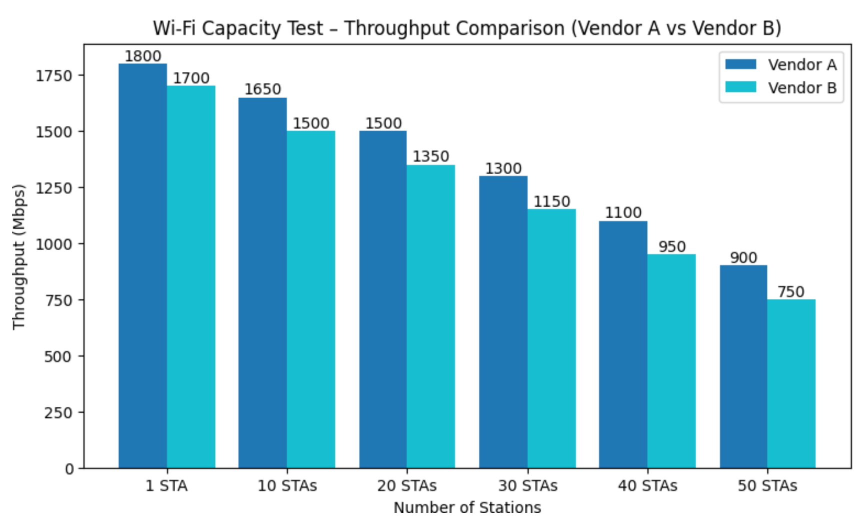
- Pass if throughput remains stable across all orientations with no significant or unexpected drops. Failure if major inconsistency or severe throughput degradation is observed across rotation angles.

Single Client Peak Throughput Test

Objective:

The Candela Wi-Fi Capacity test evaluates AP performance as the number of connected stations increases in user-defined steps, measuring per-station and aggregate throughput along with connection time, DHCP time, fairness, packet loss, and related metrics, verify scalability, fair airtime distribution, and stable overall throughput within the AP's specifications.

Observations:



- The graph compares the total Wi-Fi throughput of Vendor A and Vendor B as the number of connected clients increases.
- Both vendors show high throughput with a single client.
- Vendor A consistently maintains higher throughput, with the difference becoming more noticeable in high-density scenarios (30–50 clients).
- Overall, Vendor A demonstrates better capacity handling, scalability, and performance underload compared to Vendor B.

Test Procedure:

1. Configure the DUT and connect to an initial set of stations.
2. Start traffic and record baseline per-station and total throughput.
3. Increase the station count in defined steps and repeat the test.
4. At each step, measure overall throughput, per-station throughput, fairness, and packet loss.
5. Continue until the maximum station limit is reached.
6. Analyze whether throughput scales without major degradation and airtime are distributed.

Pass/Fail Criteria:

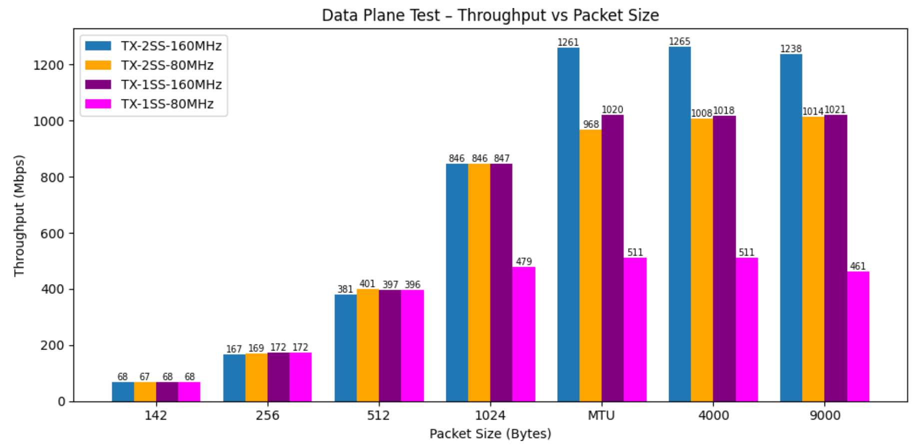
- The test passes if the AP scales without major throughput drop and maintains fair, stable connections; otherwise, it fails.

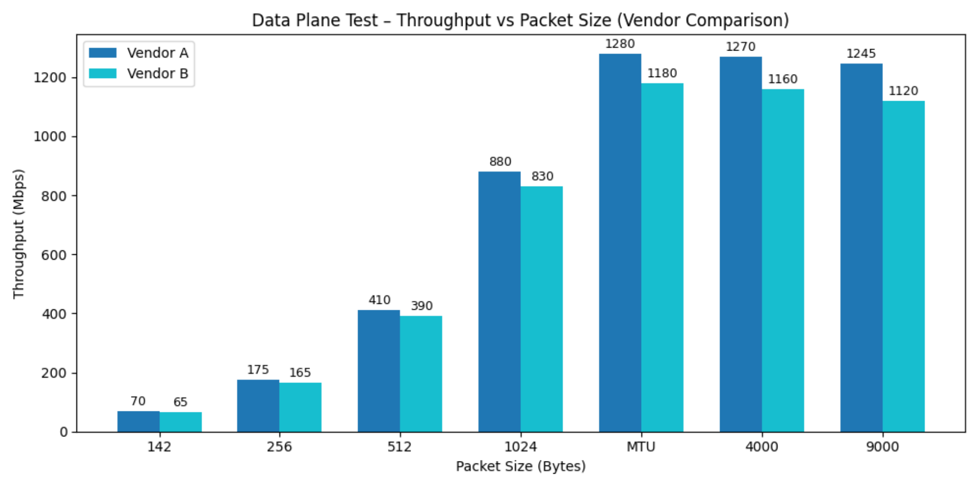
Throughput Test with different PDUs

Objective:

The Candela Wi-Fi Data Plane test automatically runs throughput measurements across all combinations of station types, MIMO modes, channel bandwidths, traffic types, directions, and frame sizes, comparing results through charts. The user defines intended load as a percentage of the theoretical PHY rate, and the test verifies that achieved throughput reaches at least 70% of the theoretical maximum under ideal conditions, enabling large-scale automated analysis to identify performance patterns and problem areas.

Observations:





- The graph shows average throughput for different traffic types, calculated over defined reporting intervals (1 minute for normal/-LL and 3 seconds for -3s).
- Datasets marked "-LL" include IP, TCP, UDP, and Ethernet headers; Armageddon low-level results also include Ethernet FCS and preamble.
- Other datasets report throughput, excluding protocol overhead.
- When "Show Opposite Traffic" is enabled, brown represents download and purple represents upload, with different shades indicating 3s, 1m, and low-level results.

Test Procedure:

1. Configure the DUT with the required band, channel, and baseline settings.
2. Define the test matrix (station types, MIMO modes, bandwidths, traffic types, directions, and frame sizes).
3. Set intended load as a percentage of theoretical PHY rates for each combination.
4. Run automated throughput tests across all combinations.
5. Collect per-combination throughput results.

6. Generate charts and reports to compare performance and identify deviations or problem patterns.

Pass/Fail Criteria:

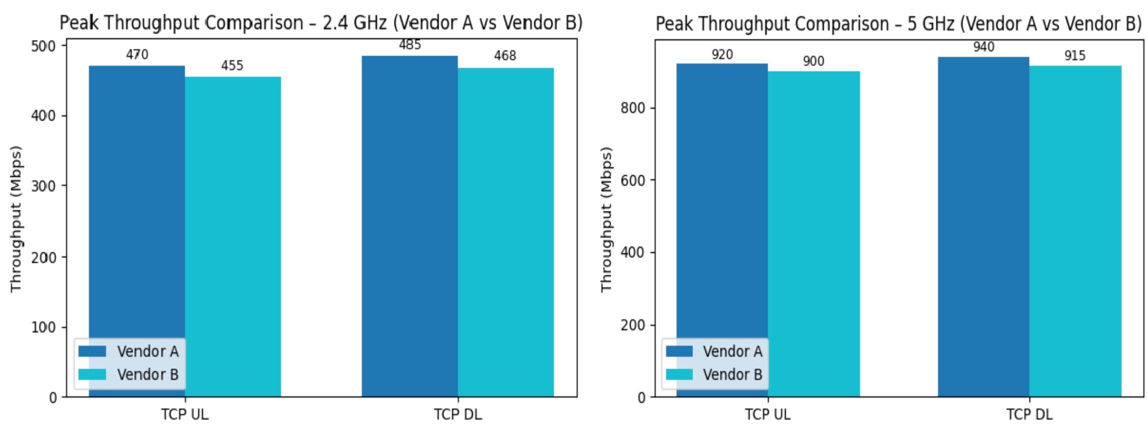
- The DUT is considered a Pass if measured throughput across all defined combinations is stable, repeatable, and within the expected percentage of theoretical PHY rates with no abnormal drops or inconsistencies; otherwise, it is considered a Fail.

IPv4/IPv6 Performance Test

Objective:

This report evaluates access point performance through client connectivity validation and peak throughput testing. It verifies stable IPv4/IPv6 connectivity for 50 clients, measures maximum single-client TCP upload and download throughput on both bands and assesses multi-client capacity under a concurrent load of 32 clients.

Observations:



- For 2.4GHz TCP Upload traffic, the observed MCS values are 97% of the packets are transmitted with MCS 11 and only 3% with MCS 10 and observed latency is 23 seconds.
- For 2.4GHz TCP Download traffic, the observed MCS values are 100% of the packets are transmitted with MCS 11 and observed latency is 17 seconds.
- For 5GHz TCP Upload traffic, the observed MCS values are 92% of the packets are transmitted with MCS 11 and 8% with MCS 10 observed latency is 8 seconds.
- For 5GHz TCP Download traffic, the observed MCS values are 100% of the packets are transmitted with MCS 11 and observed latency is 6 seconds.

Test Procedure:

1. Configure the AP for 2.4 GHz and 5 GHz operation.
2. Run client connectivity tests to associate 50 clients and verify stable IPv4 and IPv6 connections.
3. Perform single-client throughput tests to measure peak TCP upload and download rates on each band.
4. Execute multi-client capacity tests with 32 concurrent clients.
5. Collect connection success, stability, and throughput results and generate the final report.

Pass/Fail Criteria:

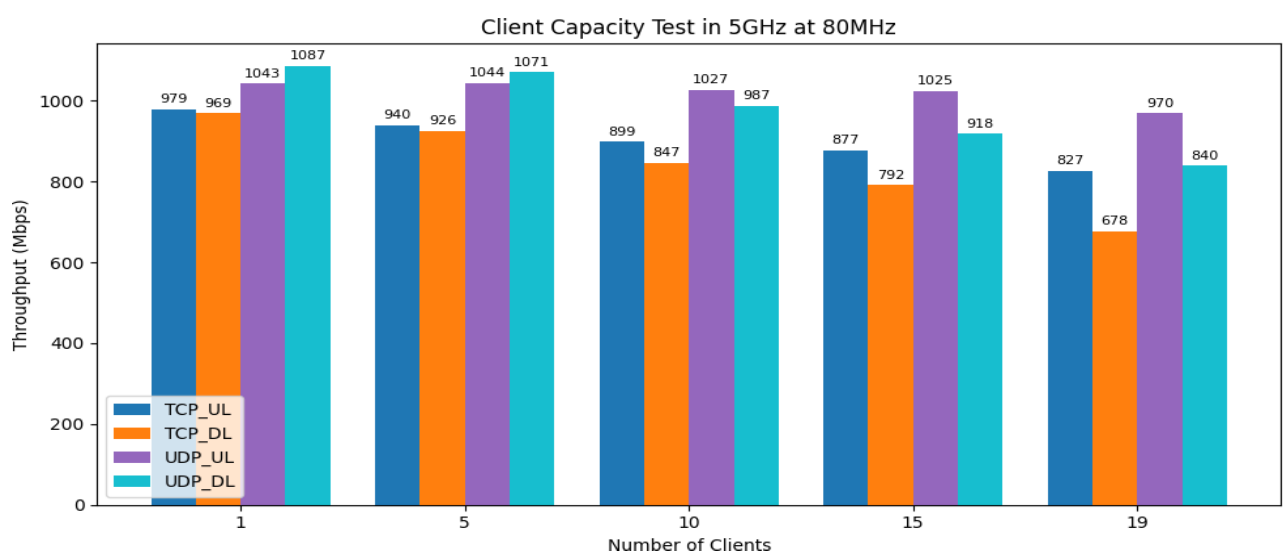
The AP is considered a Pass if it successfully connects all clients with stable IPv4/IPv6 connectivity and delivers consistent, expected single-client peak throughput and multi-client capacity performance on both 2.4 GHz and 5 GHz; otherwise, it is considered a Fail.

Client Capacity Test

Objective:

The Client Capacity Performance Test evaluates how the DUT scales with increasing client counts by measuring throughput at defined increments to assess airtime efficiency, stability, and overall performance, with the goal of identifying the maximum client load the DUT can support while maintaining acceptable throughput.

Observations:



- Throughput is highest with 1 client and gradually decreases as the number of clients increases, which is expected due to airtime sharing.
- UDP traffic achieves higher throughput than TCP across all client counts.
- Both uplink and downlink follow a consistent degradation trend as load increases.
- The DUT maintains stable and predictable performance for up to 19 clients, indicating good capacity handling.

Test Procedure:

1. AX clients were incrementally connected (1, 5, 10, 15, 20) on 5 GHz, 80 MHz, with an intended load of 1.2 Gbps across all traffic types.
2. Client performance remained consistent as client count increased.
3. Per-client throughput was evenly distributed with no major imbalance observed.
4. UDP DL and TCP DL remained mostly consistent, while UDP UL and TCP UL dropped by more than 100 Mbps at 20 clients.
5. Overall, the Vendor AP performed on par with the benchmark router in the client capacity test.

Pass/Fail Criteria:

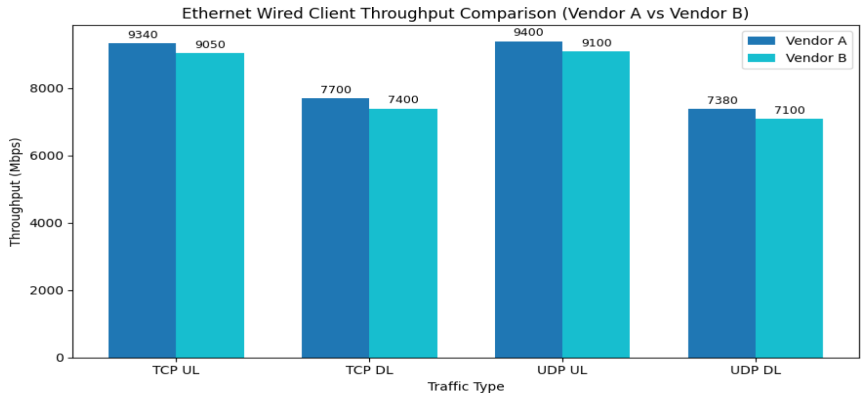
- Pass if the DUT maintains stable connections, fair per-client throughput, and consistent performance as client count increases, comparable to the benchmark router else fails.

Ethernet Wired Client Throughput Test

Objective:

This test evaluates the DUT's maximum achievable wired throughput by measuring peak uplink and downlink performance over the LAN/Ethernet interface under ideal conditions, ensuring the device delivers full expected throughput independent of Wi-Fi limitations.

Observations:



- Traffic in this topology flowed from the WAN interface to 3 LAN interfaces (LAN1+LAN2+LAN3).
- During TCP testing, the measured throughput reached a 9.34 Gbps downlink and 7.70 Gbps uplink.
- Under UDP testing, the throughput achieved a 9.40 Gbps downlink and 7.38 Gbps uplink.
- Both TCP and UDP results demonstrate high utilization of the 10G interface with stable and consistent performance.
- The upload direction consistently showed lower throughput compared to download, indicating less data transfer capacity in that direction.

Test Procedure:

1. Connect a wired client directly to DUT's LAN/Ethernet port.
2. Generate uplink and downlink traffic under ideal conditions.
3. Measure and record peak upload and download throughput.
4. Compare results against expected wired performance.

Pass/Fail Criteria:

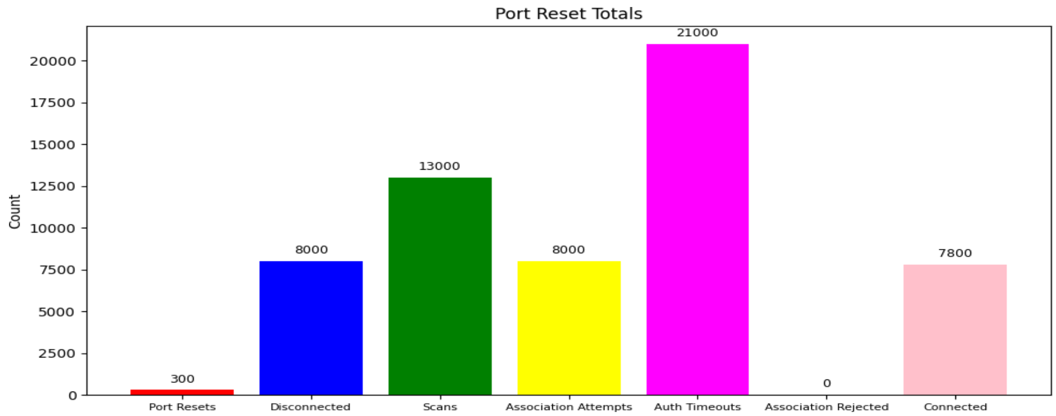
- The DUT achieves expected peak uplink and downlink throughput on the LAN/Ethernet interface under ideal conditions. The DUT does not reach expected wired throughput or shows unstable or degraded performance.

Wi-Fi Client Reset Test

Objective:

The Wi-Fi Reset test creates many Wi-Fi stations and repeatedly disconnects and reconnects random clients at random intervals to simulate enterprise or public-venue environments. When running for long durations, it stresses the AP's control and management functions. The test passes if the AP remains stable, and stations continue to successfully reconnect throughout the test.

Observations:



- Authentication timeouts and scan events are very high, indicating frequent client searching and delays/failures during authentication.
- Association attempts and disconnections are high, showing repeated connection attempts and frequent link drops.
- Connected count is much lower than attempts/timeouts, highlighting a gap between connection attempts and stable successful connections.
- Port resets are very low, and association rejections are negligible, indicating issues are mainly during scanning/authentication rather than physical or rejection-related problems.

Test Procedure:

1. Configure the DUT, create the required number of stations, and start the Port Reset test with random port selection and defined reset intervals.
2. Randomly disconnect and reconnect multiple stations concurrently and allow them to reassociate and regain connectivity.
3. Continue the test for the planned duration to simulate dynamic enterprise/public-venue behavior.
4. Monitor AP stability, reconnection of success, recovery time, and any errors, crashes, or unexpected resets.
5. Record all events and results, then generate a final report summarizing DUT stability and reconnection performance.

Pass/Fail Criteria:

The DUT passes if all stations consistently reconnect within acceptable time limits without crashes, instability, or excessive failures during random port resets; otherwise, it fails.

Advanced Test Suite

Client Connectivity with Enterprise Security

Objective:

Evaluate DUT's ability to support enterprise-grade authentication and advanced security modes, including WPA2-Enterprise, WPA3-Enterprise, Dynamic MPSK, Static MPSK, and WPA3 Suite B, by validating successful client authentication, correct RSN advertisement, and stable connectivity in both single-client and multi-client scenarios.

Observations:

Test Area	Security Mode / Feature	Method	Observation	Status
Enterprise Security	WPA2-Enterprise	EAP-TTLS	Client successfully authenticated. correct RSN and AES-CCMP observed in beacon/PCAP	Pass
Enterprise Security	WPA2-Enterprise	EAP-PEAP	Client successfully authenticated, EAP and 4-way handshake completed	Pass
Enterprise Security	WPA3-Enterprise	EAP-TTLS	Client successfully authenticated with enhanced cipher suites	Pass
Enterprise Security	WPA3-Enterprise	EAP-PEAP	Client successfully authenticated. correct RSN parameters observed	Pass
MPSK	Dynamic MPSK	Multiple PSKs via RADIUS	3 clients successfully connected to same SSID using different PSKs. mapped per client	Pass
MPSK	Static MPSK	Fixed PSK	2 clients successfully authenticated. using static MPSK; correct RSN observed	Pass
High-Security Enterprise	WPA3 Suite B (192-bit)	EAP-TLS (SHA-384)	Client failed to send authentication request after probe response (tested with MTK7915)	Fail

Test Procedure:

1. Configure the AP for each security mode (WPA2-Enterprise, WPA3-Enterprise, Dynamic MPSK, Static MPSK, WPA3 Suite B).
2. Start packet capture and connect clients using the required EAP method or PSK type.
3. Verify successful authentication, IP assignment, and stable connectivity.

4. Analyze PCAPs to confirm EAP/EAPOL exchanges and RSN information.
5. Record connection success, failures, and observed security parameters.

Pass/Fail Criteria:

Pass if clients successfully authenticate, maintain stable connectivity, and the AP advertises correct RSN, cipher, and AKM information for the configured security mode else fail.

Client Connectivity with Transition Mode & Advanced Security

Objective:

To verify the DUT's ability to support modern Wi-Fi security while maintaining backward compatibility, including WPA2/WPA3 Personal Transition Modes, WPA3-Enterprise Transition Mode, Opportunistic Wireless Encryption (OWE), and advanced enterprise security, ensuring clients connect using the correct security method and maintain stable connectivity in mixed-security environments.

Observations:

Test Area	Observation	Status
WPA2 Personal Transition Mode	WPA-PSK and WPA2-PSK clients successfully connected	Pass
WPA3 Personal Transition Mode	WPA2-PSK and WPA3-PSK clients successfully connected	Pass
WPA3 Enterprise Transition Mode	WPA2-Enterprise client successfully connected using EAP-TTLS and EAP-PEAP	Pass
OWE (Enhanced Open)	Client successfully connected using encrypted open association	Pass

Test Procedure:

1. Configure the AP for each mode: WPA2 TM, WPA3 TM, WPA3-Enterprise TM, and OWE.
2. Start packet capture and attempt client connections for each security type.
3. Verify successful association, authentication, and stable connectivity.
4. Analyze PCAPs to confirm correct RSN, AKM, and cipher information.

5. Record connection results and security behavior.

Pass/Fail Criteria:

Pass if clients successfully authenticate and associate across all transition and advanced security modes, maintain stable connections, and advertise correct RSN, AKM, and cipher parameters else fail.

Captive Portal

Objective:

The objective of this test is to validate the Captive Portal functionality of the DUT by verifying user authentication workflows, redirection behavior, session handling, and access control policies across different user roles, devices, and browsers.

Test Procedure & Expected Result:

S.No	Test Case	Procedure	Expected Result
1.	Verify redirection to captive portal	1. Connect the client to the DUT SSID with captive portal enabled. 2. Open any HTTP site and verify the browser redirects to the captive portal login page.	Client is automatically redirected to the captive portal login page when attempting to access any HTTP site.
2.	Validate login with valid credentials	1. Enter valid credentials on the captive portal page and verify successful authentication and network access.	Client successfully authenticates and gains full network access after entering valid credentials.
3.	Verify behavior with invalid credentials	1. Enter invalid username /password and ensure the system denies access.	Login fails, and the client remains blocked from accessing the network when invalid credentials are used.

4.	Check timeout behavior after inactivity	1. Log in to the client. 2. Keep the client idle until the session timeout. 3. Then attempt browsing to confirm the session expires.	Client session expires after configured inactivity timeout and user is required to log in again.
5.	Verify behavior on various devices	1. Connect laptops, smartphones, and tablets to verify consistent captive portal redirection and login.	Captive portal loads correctly, and login works consistently across laptops, smartphones, and tablets.
6.	Test with multiple browsers	1. Access the captive portal using Chrome, Firefox, Safari, and Edge to confirm consistent behavior and login flow.	Captive portal displays properly, and authentication succeeds on all supported browsers (Chrome, Firefox, Safari, Edge).
7.	Confirm HTTPS redirection works	1. Attempt to open an HTTPS site before logging in and verifying captive portal interception or redirection.	HTTPS traffic is intercepted or redirected to the captive portal according to AP capabilities and configuration.
8.	Validate session persistence during roaming	1. Log in to the client. 2. Roam between APs under the same SSID. 3. Verify that the user session remains active.	Client maintains authenticated session when roaming between APs within the same SSID without needing to re-login.
9.	Ensure proper logout behavior	1. Log in to the client. 2. Click the logout button. 3. Confirm that the client is redirected to the login page when browsing again.	After logging out, the client loses access and is redirected to the captive portal upon accessing any website.

10.	Validate login attempt limits	1. Attempt repeated failed logins to verify lockout or rate-limit behavior (if configured).	After exceeding the allowed number of failed login attempts, the client is temporarily blocked or receives an error message.
11.	Verify access to walled garden websites	1. Before logging in, try accessing URLs in the walled-garden list to confirm they open without authentication.	Clients can access configured wall garden sites without authentication while other sites remain blocked.
12.	Verify behavior with VLANs	1. Connect clients mapped to different VLANs and verify captive portal redirection, and login operates correctly on each VLAN.	Captive portal redirection and authentication behave correctly for clients assigned to different VLANs.

MAC ACL

Objective:

The objective of the MAC ACL Test is to verify that the DUT correctly applies to MAC address–based access control by allowing or blocking client connections according to the configured allow and deny lists.

Observations:

- DUT consistently enforced MAC to allow and deny policies, permitting only authorized clients while reliably blocking unauthorized MAC addresses with clear log indications.
- Dynamic MAC ACL updates were applied in real time, immediately disconnecting denied clients and allowing reconnection once restrictions were removed.

Test Procedure:

1. Configure the DUT as per Table 1.1.
2. Configure the DUT with MAC to allow and deny lists as per the test scenario.
3. Attempt client associations using allowed, denied, and non-listed MAC

addresses.

4. Dynamically update MAC ACL entries while clients are connected.
5. Monitor client connectivity behavior, association responses, and DUT logs.

Pass/Fail Criteria:

- Pass allowed clients to connect successfully, denied clients are blocked or disconnected immediately (including during dynamic updates), and DUT logs accurately reflect MAC ACL enforcement; otherwise Fail.

Client isolation Test

Objective:

The objective of this test is to verify that client isolation functionality on a Wi-Fi access point prevents direct communication between wireless clients connected to the same SSID, while still allowing clients to communicate with the network gateway or upstream resources.

Observations:

- Wireless clients are unable to communicate directly with each other when client isolation is enabled.
- All wireless clients can reach the default gateway and upstream network without restriction.
- Client isolation behavior remains consistent across different traffic types.

Test Procedure:

1. Enable client isolation on the DUT for the target SSID.
2. Associate multiple wireless stations to the same SSID.
3. Initiate traffic (ICMP/TCP) between wireless stations.
4. Verify that inter-client communication is blocked.
5. Initiate traffic from wireless stations to the default gateway.
6. Verify that gateway communication is allowed.

Pass/Fail Criteria:

The test is considered **PASS** if: All wireless client-to-client traffic is blocked, and all wireless client-to-gateway traffic is allowed.

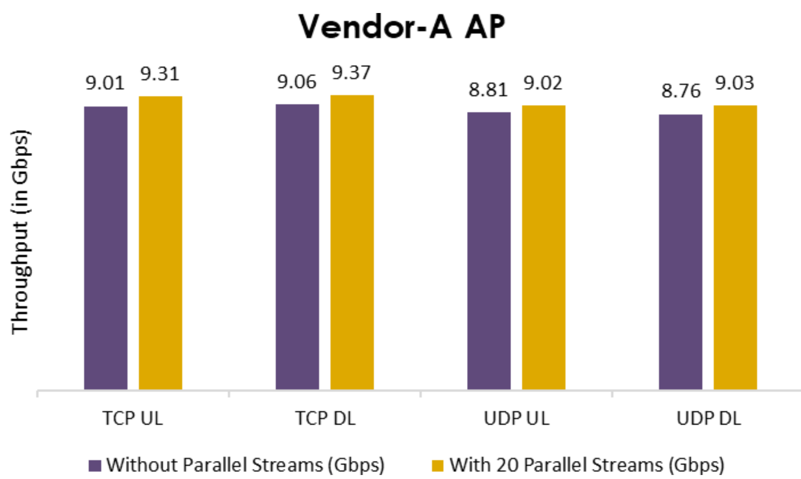
SFP to Ethernet Backhaul Testing

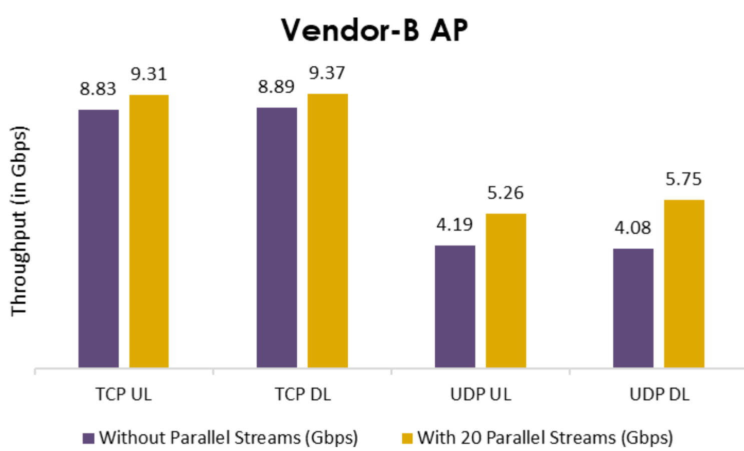
Objective:

The objective of this test is to verify the throughput and stability over the SFP to Ethernet backhaul link for both two-AP and single-AP topologies. This includes UDP and TCP traffic in uplink and downlink directions, ensuring reliable connectivity and no packet. loss or link failures.

Observations:

- Both Vendor-A and Vendor-B achieved stable TCP throughput, indicating reliable and consistent data transfer performance.
- Vendor-B showed lower UDP throughput due to observed packet loss, especially under high traffic load, which reduced the effective throughput.
- Vendor-A did not exhibit noticeable packet loss and maintained stable UDP throughput across the test duration.





Test Procedure:

1. Configure the AP(s) as per Table 1.1 and establish Ethernet ↔ SFP backhaul (single-AP or two-AP topology as applicable).
2. Connect the server to the Ethernet port and the client to the SFP port.
3. Run UDP or TCP traffic for 15 minutes by establishing the server on the Ethernet port and the client on the SFP port, as per the test variation.
4. Monitor link and AP stability during the test.
5. Record throughput and packet loss.
6. Repeat the same procedure for UDP UL, UDP DL, TCP UL, and TCP DL.

Pass/Fail Criteria:

Achieved throughput must be 80-90% of the ethernet port capability.

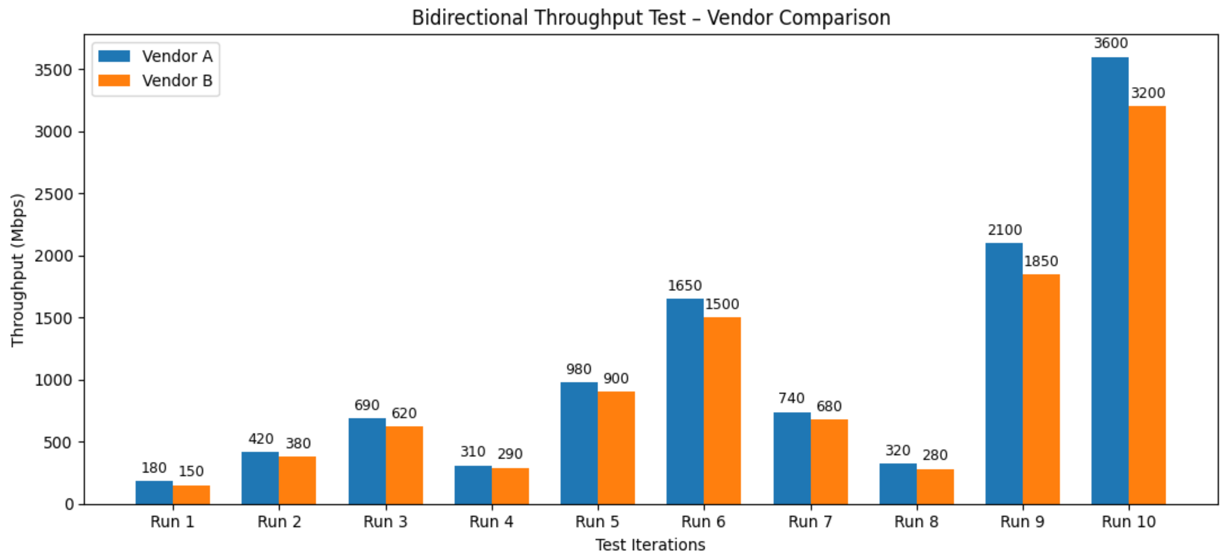
Bi-Directional Throughput Test

Objective:

The Bidirectional Throughput Test measures the DUT's maximum performance with a single station running simultaneous upload and download traffic. The test is conducted at three different attenuation levels to represent varying distances. TCP is first used to determine peak achievable speed, followed by bidirectional UDP traffic at slightly below the measured TCP maximum.

Observations:

- The DUT was tested across 2.4, 5, and 6 GHz bands in N/AC and AX modes with 2 spatial streams.
- Peak TCP uplink and downlink throughput were measured first, followed by bidirectional UDP testing at ~45% of TCP throughput.
- The DUT maintained stable bidirectional performance across multiple attenuation levels, with expected throughput reduction at higher attenuation and packet error rates within acceptable limits.
- Overall, the DUT demonstrated strong and consistent bidirectional scaling, with the highest throughput observed in 6 GHz AX configurations, indicating efficient simultaneous UL/DL handling.



Test Procedure:

1. Execute tests on 2.4, 5, and 6 GHz in N/AC and AX modes with stations set to 2 spatial streams.
2. Configure the station and attenuate to the required close and defined attenuation levels, then associate with a client to the DUT.
3. Run 120-second TCP downlink and uplink tests and record peak throughput.
4. Run 120-second bidirectional UDP traffic at ~45% of TCP throughput and record uplink/downlink packet loss.
5. Repeat the above steps across all attenuation levels and modes and log all results.

Pass/Fail Criteria:

For each of the test configurations. The Packet Error Rate (PER) for each STA SHALL achieves less than 01%.

Multicast Traffic Test

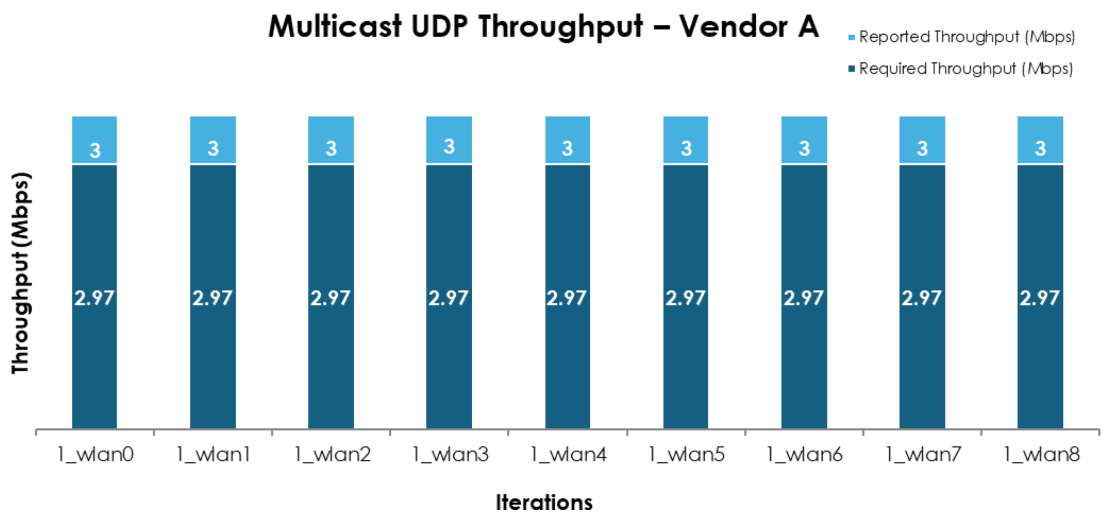
Objective:

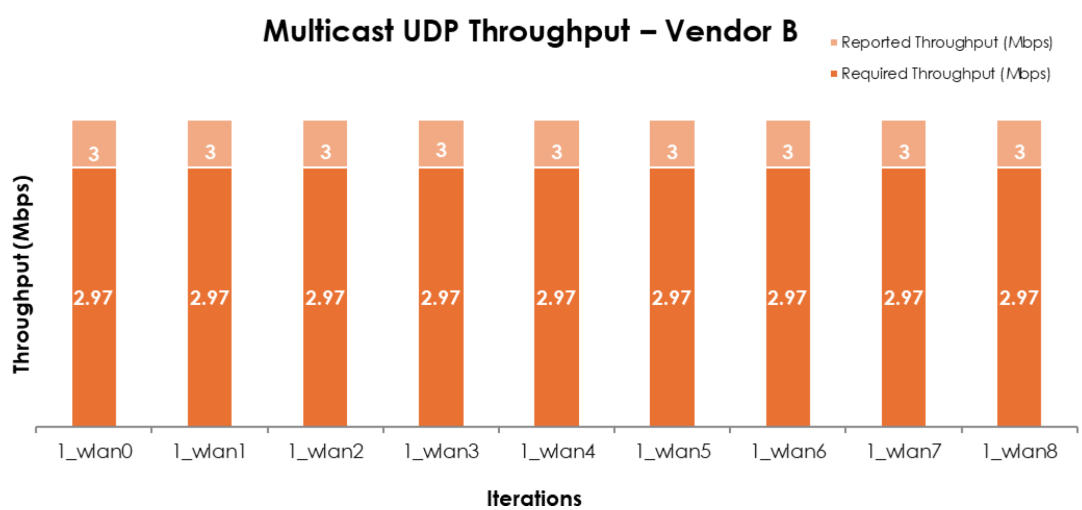
The objective of the Multicast Test is to verify correct downlink multicast operation with multiple stations at different emulated distances. This test ensures reliable multicast delivery across varying signal conditions where multicast rate control is not applied.

Observations:

- Multicast throughput remains consistent across all iterations and meets the configured transmission rate.

- All multicast receivers achieve throughput above the required passing threshold, regardless of emulated distance.
- Results indicate stable and reliable multi-cast delivery with no receiver starvation.





Test Procedure:

1. Configure the test environment with a baseline emulated distance.
2. Establish LAN connectivity and create three groups of stations; each group placed at a different emulated distance (short, medium, and long).
3. Configure a single UDP IPv4 multicast transmitter on the Ethernet interface with the required multicast rate.
4. Configure a multicast receiver on each station using the same multicast IP and port.
5. Start multicast transmission and allow time for IGMP group membership to

propagate.
6. Run multicast traffic for a fixed duration and record per-station throughput.
7. Stop multicast traffic and disassociate stations.
8. Repeat the test for all required Wi-Fi bands and operating modes by reconfiguring the DUT and stations accordingly.

Pass/Fail Criteria:

For each configuration, each multicast receiver endpoint must receive at least 99% of the transmitted data rate.

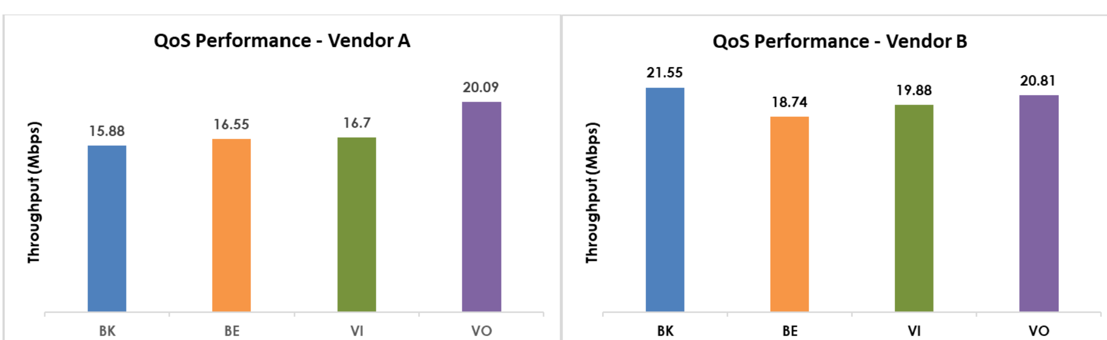
Quality of Service

Objective:

The objective of the Quality of Service (QoS) Test is to verify that the AP correctly prioritizes network traffic based on QoS classifications, ensuring higher-priority traffic receives preferred handling over lower-priority traffic.

Observations:

- Vendor-A AP shows expected QoS behavior, where Voice (VO) and Video (VI) traffic achieve higher throughput than Best Effort (BE) and Background (BK), indicating correct EDCA/AIFSN-based prioritization.
- Vendor-B AP does not follow the expected QoS precedence; Best Effort / Background traffic achieves higher throughput than Voice, despite correct EDCA parameters being advertised in beacon frames.
- Packet capture analysis shows lower QoS frame counts for VO/VI TIDs on Vendor-B, while higher-priority traffic is not effectively scheduled, even under reduced load.
- A high RTS/CTS overhead (~30% of wireless frames) is observed on Vendor-B, which introduces additional contention and reduces effective airtime for QoS-sensitive traffic, leading to improper prioritization despite zero packet loss.



Test Procedure:

1. Configure the DUT as per Table 1.1.
2. Associate a client with the DUT.
3. Create four traffic streams (VO, VI, BE, BK) and run traffic for all streams concurrently.
4. Observe and record airtime distribution and traffic priority enforcement across the streams.

Pass/Fail Criteria:

The traffic priority order must follow (VO > VI > BE > BK).

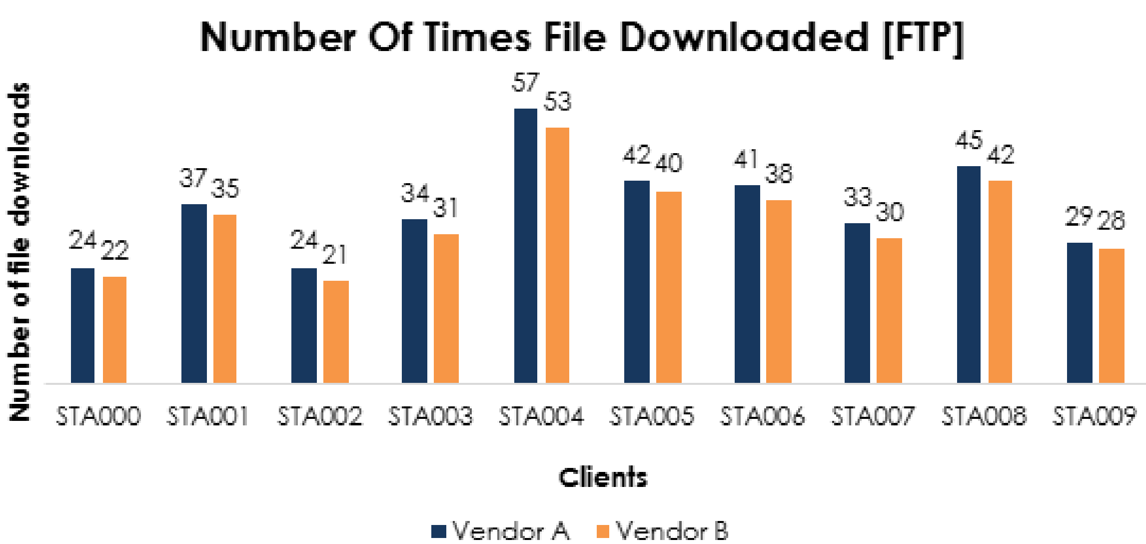
Application Layer Data Transfer (FTP/HTTP) Test

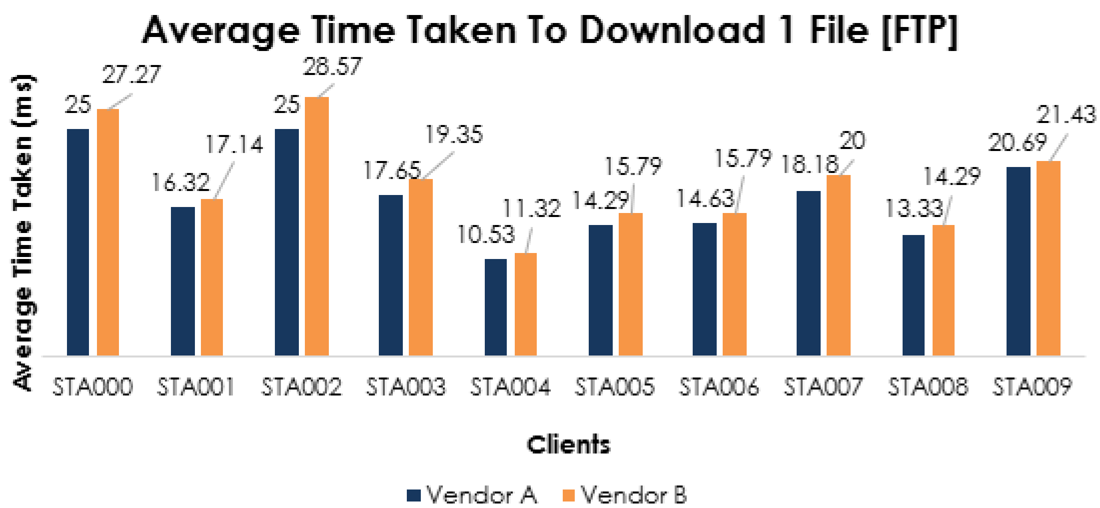
Objective:

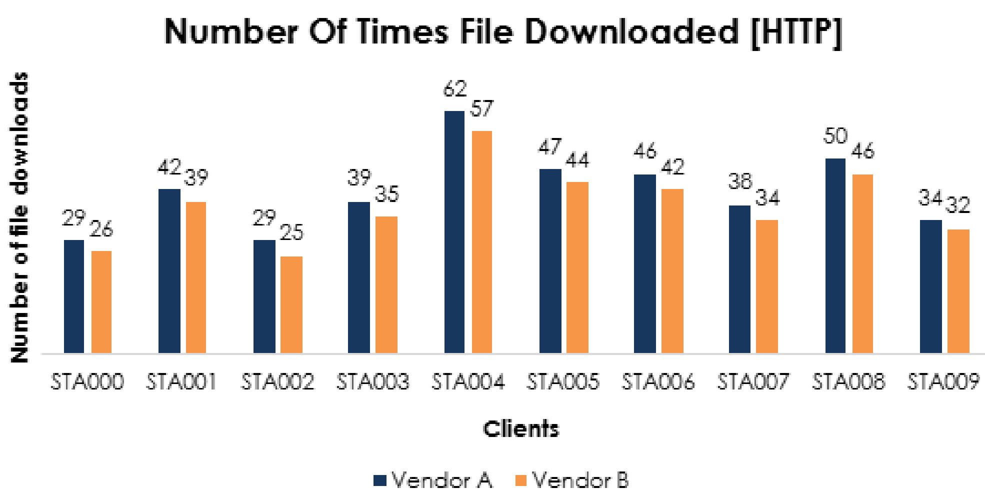
The objective of this test is to verify that multiple clients connected to the AP can reliably perform application-layer data transfers using FTP and HTTP protocols. This test validates stable file downloads and webpage/content access under sustained client load, ensuring consistent transfer performance, session reliability, and predictable user experience across different client platforms.

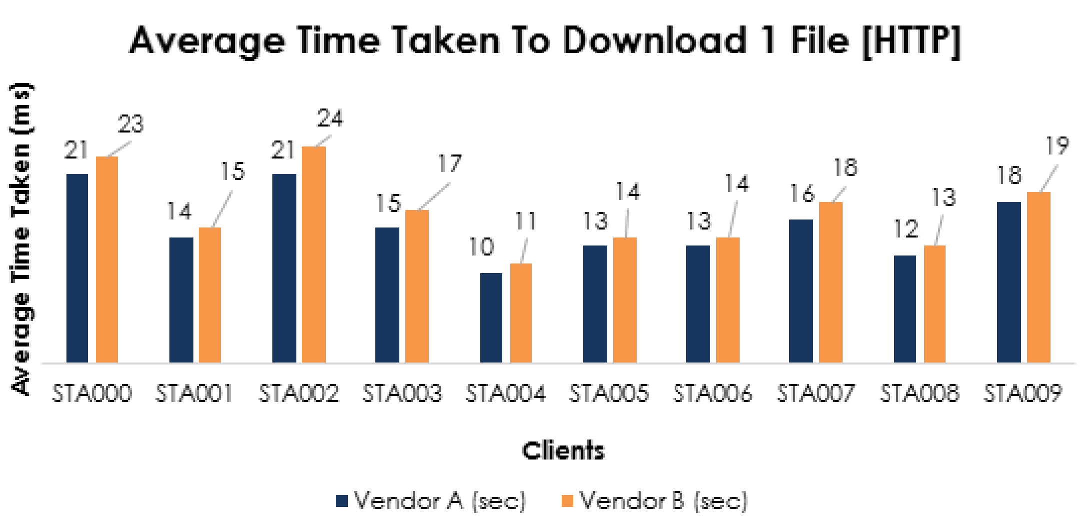
Observations:

- Vendor A consistently outperformed Vendor B across FTP and HTTP tests, achieving higher transfer completion counts and lower average transfer times (by ~1–3 seconds) across most clients.




Average Time Taken To Download 1 File [FTP]
Average Time Taken (ms)
25
27.27
16.32
17.14
25
28.57
17.65
19.35
10.53
11.32
14.29
15.79
14.63
15.79
18.18
20
13.33
14.29
20.69
21.43
STA000
STA001
STA002
STA003
STA004
STA005
STA006
STA007
STA008
STA009
Clients
Vendor A
Vendor B


Number Of Times File Downloaded [HTTP]
Number of file downloads
29
26
42
39
29
25
39
35
62
57
47
44
46
42
38
34
50
46
34
32
STA000
STA001
STA002
STA003
STA004
STA005
STA006
STA007
STA008
STA009
Clients
Vendor A
Vendor B


Average Time Taken To Download 1 File [HTTP]
Average Time Taken (ms)
21
23
14
15
21
24
15
17
10
11
13
14
13
14
16
18
12
13
18
19
STA000
STA001
STA002
STA003
STA004
STA005
STA006
STA007
STA008
STA009
Clients
Vendor A (sec)
Vendor B (sec)

Test Procedure:

- Configure the DUT as per Table 1.1 and set up FTP and HTTP servers.
- Connect 10 clients to DUT.
- Perform continuous 1 GB file downloads using FTP and webpage/content downloads using HTTP/HTTPS for a duration of 10 minutes.
- Record transfer counts, per-transfer time (min/avg/max), and monitor session stability.

Pass/Fail Criteria:

- Pass if all clients successfully complete FTP and HTTP transfers without session drops or retries while maintaining stable and consistent transfer performance under sustained load; otherwise Fail.

Automatic Channel Selection

Objective:

The Automatic Channel Selection Test (ACS) intends to verify that the DUT AP can select a good working channel in congested environments.

Observations:

```
root@GGC4EQ0453460029:~# iw dev
phy#0
        Interface ap_tt0
                ifindex 19
                wdev 0x8
                addr d0:cb:dd:83:03:46
                ssid Spindle - 0029
                type AP
                Power mode: 0
                link 0:
                  addr d0:cb:dd:83:03:46
                  channel 11 (2462 MHz), width: 20 MHz, center1: 2462 MHz
                  txpower 27.00 dBm
                link 1:
                  addr d0:cb:dd:83:03:47
                  channel 36 (5180 MHz), width: 160 MHz, center1: 5250 MHz
                  txpower 24.00 dBm
                link 2:
                  addr d0:cb:dd:83:03:48
                  channel 101 (6455 MHz), width: 320 MHz, center1: 6425 MHz
                  txpower 25.00 dBm
```

```
phy#0
        Interface ap_tt0
                ifindex 19
                wdev 0x8
                addr d0:cb:dd:83:03:46
                ssid Spindle - 0029
                type AP
                Power mode: 0
                link 0:
                  addr d0:cb:dd:83:03:46
                  channel 11 (2462 MHz), width: 20 MHz, center1: 2462 MHz
                  txpower 27.00 dBm
                link 1:
                  addr d0:cb:dd:83:03:47
                  channel 128 (5640 MHz), width: 320 MHz, center1: 5650 MHz
                  txpower 24.00 dBm
                link 2:
                  addr d0:cb:dd:83:03:48
                  channel 101 (6455 MHz), width: 320 MHz, center1: 6425 MHz
                  txpower 25.00 dBm
```

- Initially, the 5Ghz band is at channel 36, 160MHz but after ACS happened it selected channel 128 320MHz which is not an overlapping channel to the initial channel.

Test Procedure:

1. Configure multiple stations and an interferer with AP on predefined channels.
2. Power on the DUT with ACS enabled.
3. Allow the DUT to scan the RF environment.
4. Record the channel selected by the DUT.
5. Repeat the test with different interferer configurations across 2.4G, 5G, and 6G bands.
6. Validate whether the DUT avoids busy/prohibited channels and selects a cleaner channel.

Pass/Fail Criteria:

- The DUT is considered a Pass if it selects a channel that does not overlap with the interferer's AP and is not in the prohibited channel list. It is considered a Fail if it selects the same or an overlapping channel as the interferer AP, or any restricted channel.

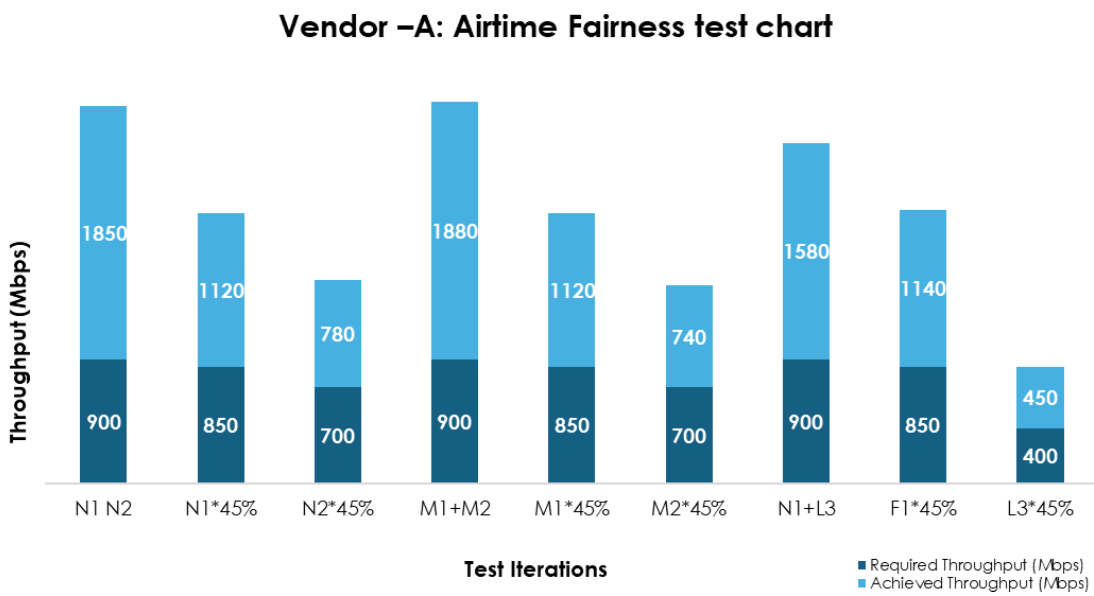
Airtime Fairness Test

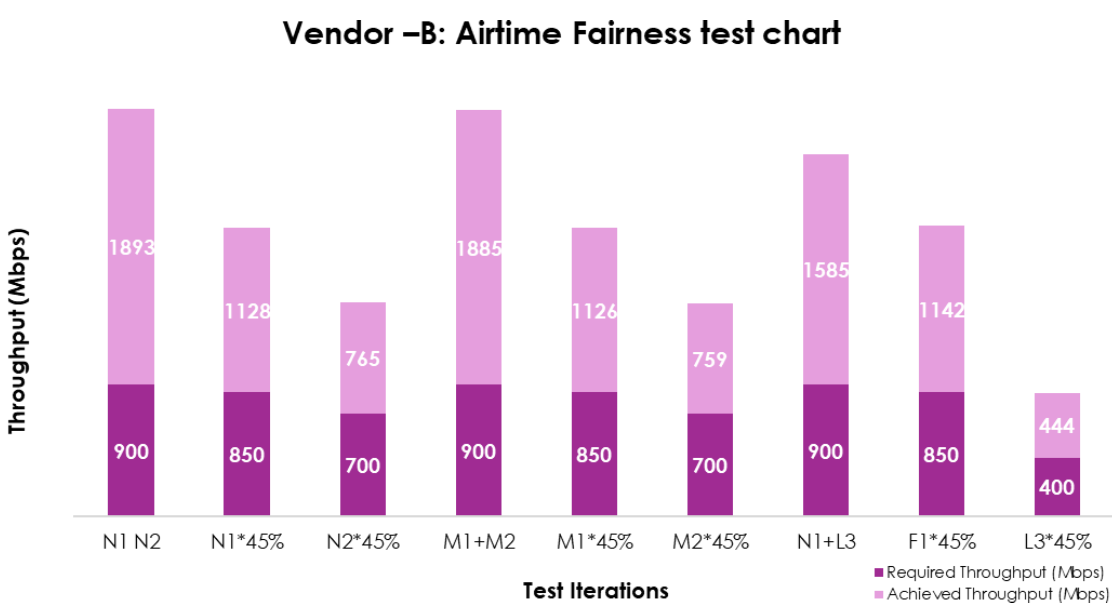
Objective:

The Airtime Fairness test verifies fair airtime distribution between two stations operating under different conditions. Baseline capacity is measured using TCP traffic, followed by concurrent UDP traffic to evaluate fairness under load.

Observations:

- Aggregate throughput across all tested bands and bandwidths remains above the required threshold, indicating effective airtime distribution.
- Fairness performance is consistent even as channel bandwidth increases, showing no starvation of lower-capability stations.
- Higher bands (5 GHz and 6 GHz) demonstrate improved aggregate throughput while maintaining fairness under congestion.
  No test iteration shows a sustained drop below the required throughput level.





Test Procedure:

1. Configure the DUT and stations in the required operating mode, with STA1 and STA2 in optimal configuration and STA3 in legacy or single-stream mode as applicable.
2. Associate STA1 and STA2 with DUT and establish LAN connectivity.
3. Measure standalone downlink TCP throughput for each associated station to determine baseline capacity.
4. Configure concurrent downlink UDP traffic using a fixed percentage of the measured TCP throughput for each station.
5. Run simultaneous UDP traffic and record per-station throughput.
6. Modify station conditions by introducing attenuation or replacing STA2 with a legacy-mode station.
7. Repeat TCP baseline and UDP for concurrent traffic measurements.
8. Execute the above steps for all required operating modes and configurations.

Pass / Fail Criteria:

For each UDP measurement, the throughput shall be at least 45% of the TCP Throughput Max speeds reported on the station being tested. This ensures that the AP properly limits the over-driven STA1 connection and gives the other station a fair amount of airtime.

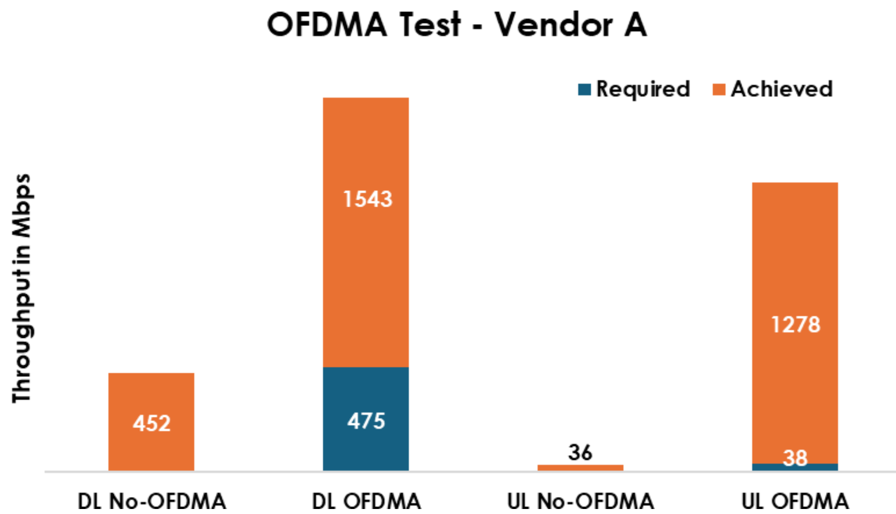
OFDMA Throughput test

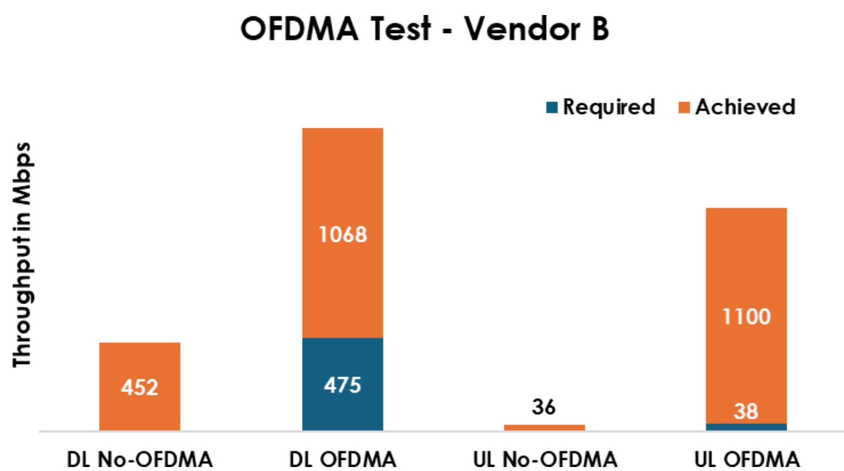
Objective:

The objective of the OFDMA Throughput Test is to evaluate the impact of OFDMA on overall network throughput by comparing performance with OFDMA enabled and disabled. This test verifies that enabling OFDMA improves efficiency and throughput when multiple stations are simultaneously transmitting moderate-speed UDP traffic along with a high-speed TCP flow.

Observations:

- Enabling OFDMA results in a significant throughput improvement over non-OFDMA operation for both downlink and uplink on both vendors.
- Vendor A achieves higher downlink OFDMA throughput compared to Vendor B, indicating more efficient downlink resource scheduling.
- Uplink OFDMA throughput improves substantially for both vendors, with Vendor A showing a slightly higher gain.
- In non-OFDMA mode, both vendors exhibit similar baseline performance, highlighting that the observed gains are primarily due to OFDMA enablement.





Test Procedure:

1. Configure the DUT as per table 1.1 with OFDMA disabled.
2. Set the attenuation to medium distance.
3. Establish the LAN connection, create 32 stations, and allow all stations to associate with the DUT.
4. Configure UDP download traffic with 300-byte payload on 31 stations.
5. Configure a single TCP download connection on the remaining station and set it to run at maximum speed.
6. Start all traffic streams and allow traffic to ramp up for 30 seconds.
7. Measure the aggregate throughput of all 32 stations over a 2-minute duration.
8. Record the TCP throughput and the sum of UDP throughput.
9. Enable OFDMA on the DUT.
10. Repeat the above steps with OFDMA enabled.

Pass/Fail Criteria:

- Pass if the total UDP and TCP throughput with OFDMA enabled is at least 105% of the total throughput measured with OFDMA disabled or else failed.
- Pass if the total UDP throughput with OFDMA enabled is at least 95% of the total UDP throughput measured with OFDMA disabled or else failed.

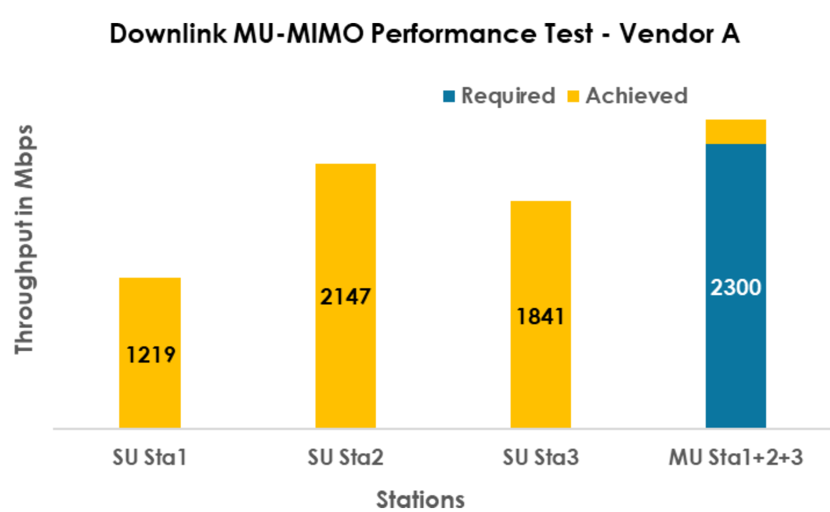
Downlink MU-MIMO Performance Test

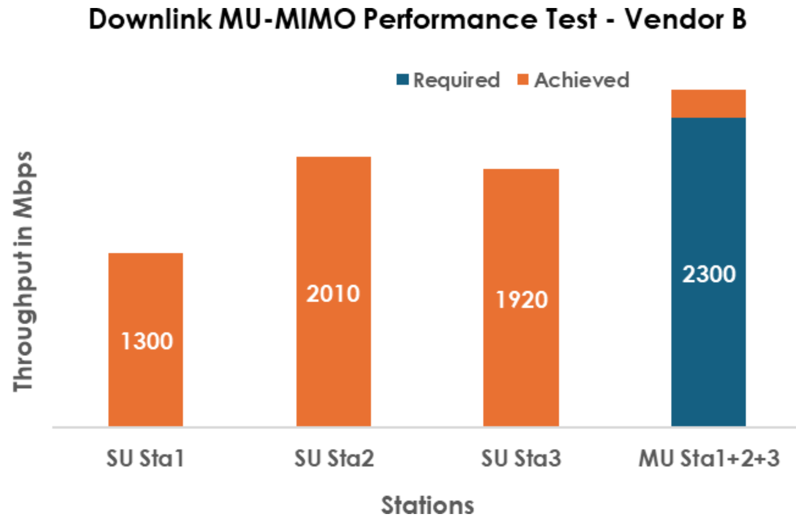
Objective:

The objective of this test is to evaluate downlink MU-MIMO performance by comparing single-station and simultaneous multi-station throughput. The test verifies the access point’s ability to efficiently transmit data to multiple clients in parallel without significant loss in aggregate throughput.

Observations:

- When stations were tested individually, higher per-station throughput was observed due to exclusive channel access.
- With MU-MIMO enabled and multiple stations active simultaneously, the access point successfully served all stations in parallel.
- Aggregate throughput under MU-MIMO operation remained a significant percentage of the summed single-station throughput.
- No single station experienced starvation during simultaneous downlink transmission.





Test Procedure:

1. Configure the DUT as per table 1.1.
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 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. Repeat steps 1 through 6 for each DUT configuration.

Pass / Fail Criteria:

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.

Interference Testing (ACI/CCI)

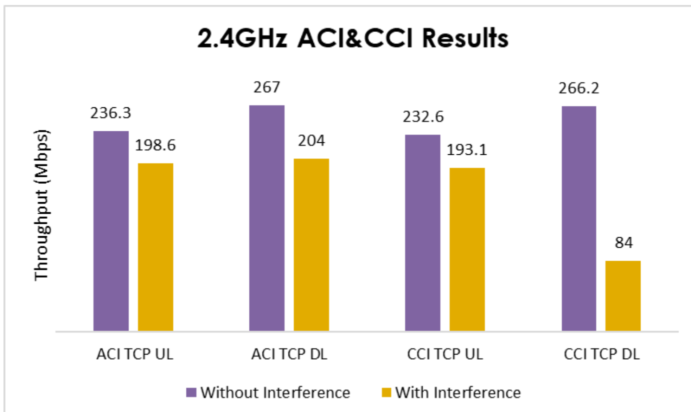
Objective:

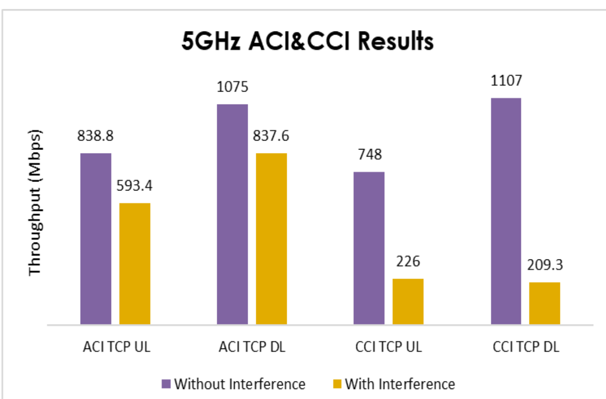
The objective of this test is to evaluate the performance of DUT when exposed to different levels of co-channel and adjacent-channel interference.

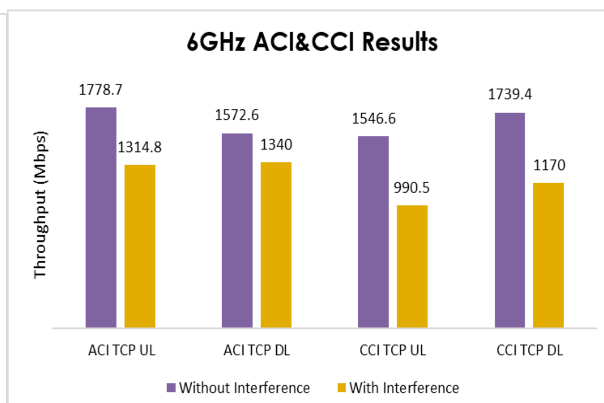
This test helps determine how well the DUT can maintain throughput, stability, and connectivity under noisy RF conditions.

Observations:

- The DUT successfully connected and operated on 2.4 GHz, 5 GHz, and 6 GHz bands with stable client associations.
- Under co-channel interference, DUT maintained good and consistent throughput across all bands.
- Higher throughput was observed with adjacent channel interference, which is expected due to reduce contention.







Test Procedure:

1. Configure the DUT as per table 1.1.
2. Connect a client to the DUT on the 2.4GHz band in the highest standard supported (802.11ax/be).
3. Create an Alien AP (VAP) operating on the same channel as DUT and connect a station to the VAP.
4. Start interference traffic and the actual traffic (TCP downlink) between the station and DUT at the same time.
5. Record the RSSI, link rates, achieved throughput, and other KPIs.

6. Now configure the Alien AP operating on an adjacent channel as that of DUT and connect a station to the VAP.
7. Repeat steps 3-7 and measure the ACI performance.

Pass/Fail Criteria:

Baseline (Without Interference):

- PASS if the DUT achieves ≥ 70% of the PHY rate (for TCP DL and UDP, as applicable).
- FAIL if achieved throughput is < 70% of the PHY rate.

With Interference (CCI / ACI):

- PASS if the DUT achieves throughput ≥ 50% of the baseline (no-interference) throughput for the same band, channel width, and traffic type (TCP DL / UDP).
- FAIL if achieved throughput is < 50% of the baseline throughput.

Stability (applies to both cases):

- FAIL if any link drops, DUT resets, or station disconnects occur during the run.

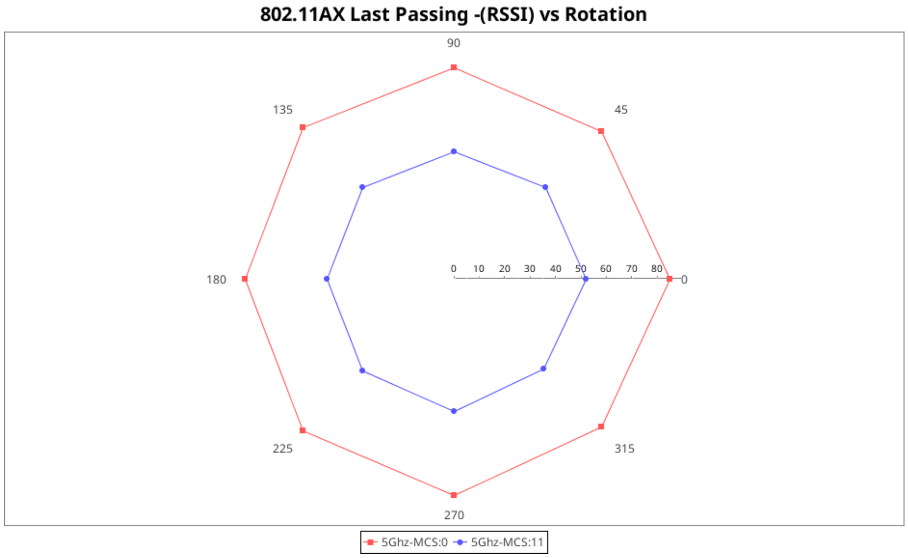
Receiver Sensitivity

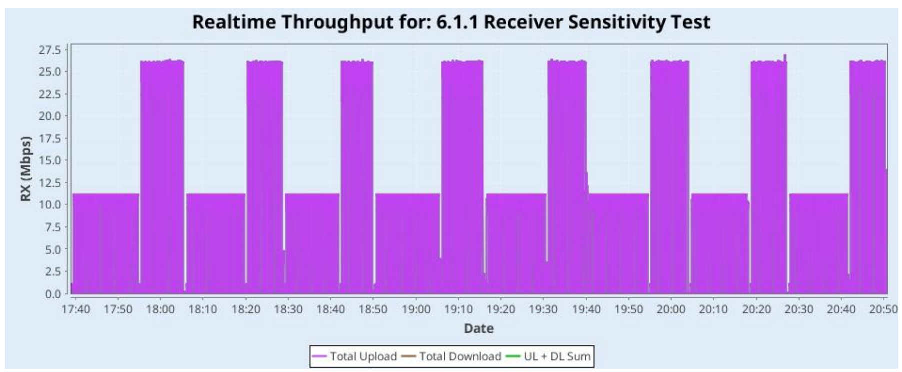
Objective:

The objective is to assess the receiver's sensitivity of the DUT by gradually increasing attenuation between the DUT and STA and observing the point at which the link degrades. This test evaluates the DUT's ability to correctly receive and demodulate weak signals, transition smoothly across coding schemes, and maintain stable connectivity under reduced signal conditions, providing an approximate indication of receiver sensitivity in a radiated test environment.

Observations:

- Throughput remains stable at lower attenuation levels and degrades gradually as attenuation increases, indicating expected receiver sensitivity behavior.
- Smooth transition between MCS levels is observed with no abrupt drops, showing proper rate adaptation.
- Performance remains consistent across all 45° spatial rotations, with no major directional sensitivity issues.





Test Procedure:

1. Configure the DUT as per Table 1.1.
2. Allow the STA to associate with the DUT.
3. Set the attenuator(s) to 0 dB.
4. Enable packet transmission from the STA to the DUT for 20 seconds.
5. Record the Packet Error Rate (PER).
6. Increase the attenuation in 1 dB steps and repeat Steps 4-6 until the PER exceeds 10%. Record the corresponding attenuation value as the approximate receiver's sensitivity.
7. Rotate the DUT by 45 degrees and repeat Steps 3-7 until a full 360-degree rotation is completed. Calculate the average receiver's sensitivity across all orientations.

Pass/Fail Criteria:

Standard	MCS Index	Modulation	Required Receiver Sensitivity (dB)
802.11ax-2.4GHz	0	BPSK	49
802.11ax-2.4GHz	11	1024-QAM	26
802.11ax-5GHz	0	BPSK	39
802.11ax-5GHz	11	1024-QAM	14

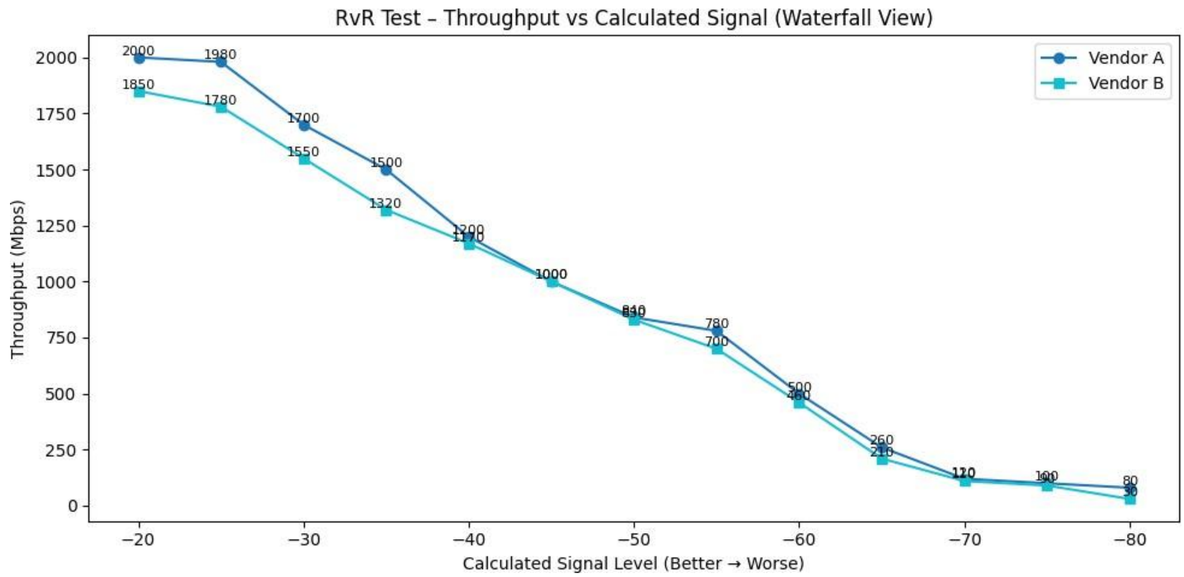
Rate vs Range Test

Objective:

The purpose of the Rate vs Range test is to evaluate DUT throughput performance over distance, where distance is emulated using attenuation steps. Throughput is measured at each step and correlated with calculated signal level and RSSI, to understand how performance degrades with range and plot rate adaptation behavior.

Observations:

- Throughput gradually decreases as attenuation increases, showing expected rate-vs-range behavior.
- Higher throughput is achieved at stronger signal levels, with smooth degradation as RSSI drops.
- PHY rate and link rate adapt downward with increasing attenuation.
- Performance trends are consistent across traffic types and bands.
- Packet loss increases only at higher attenuation levels, where the link approaches sensitivity limits.
- DUT maintains connectivity across multiple attenuation steps before throughput collapses.



Test Procedure:

1. Configure the DUT and station with the required band, bandwidth, and traffic type, and start testing at the lowest attenuation.
2. Run throughput traffic and record throughput, RSSI, and PHY rate.
3. Increment attenuation in defined steps to emulate increasing distance.
4. Repeat traffic tests at each attenuation level and log throughput, signal, PHY rate, and packet loss.
5. Plot the collected data to generate rate-vs-range curves.

Pass/Fail Criteria:

Pass if the DUT maintains stable connectivity with smooth throughput degradation, proper rate adaptation, and acceptable packet loss until near sensitivity limits else fail.

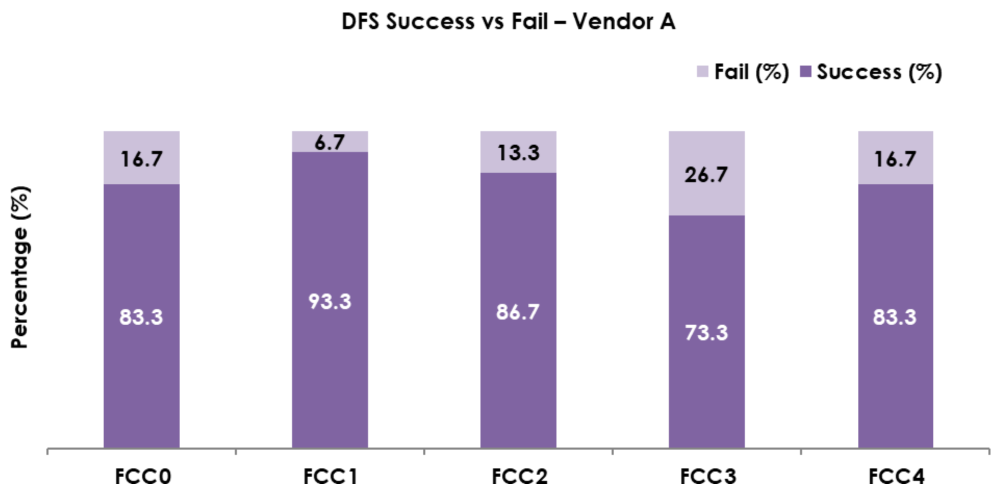
Dynamic Frequency Selection (DFS)

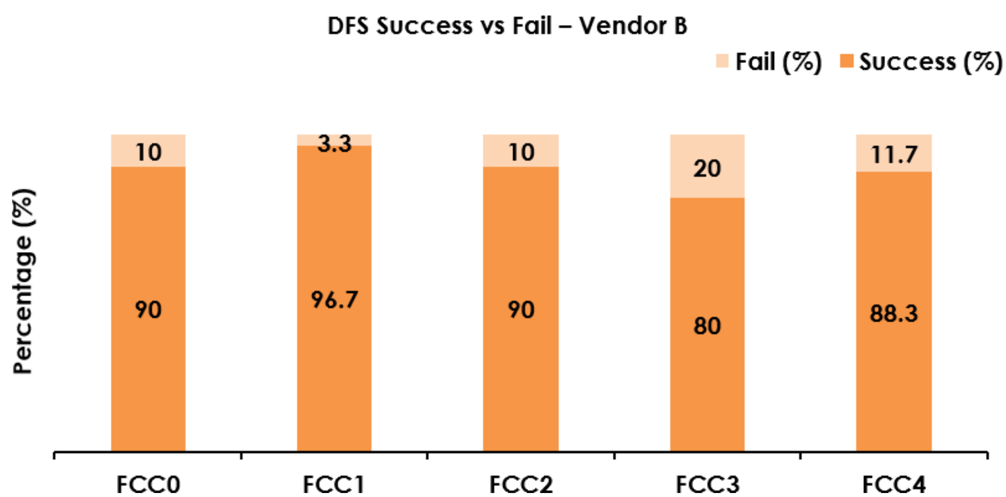
Objective:

The objective of this test is to verify that the DUT correctly supports Dynamic Frequency Selection (DFS) by detecting radar signals, notifying clients via CSA, and moving to a valid channel within regulatory timelines. The test also validates compliance with DFS requirements such as CAC, channel move time, non-occupancy period, and radar detection accuracy.

Observations:

- Both Vendor A and Vendor B demonstrate high DFS success rates across all FCC test cases, indicating correct DFS detection and channel handling behavior.
- Vendor B shows slightly higher success percentages overall, particularly in FCC0–FCC2, while both vendors experience the highest failure rate in FCC3.
- The results indicate consistent DFS compliance, with performance variations primarily dependent on test case complexity.





Test Procedure:

1) Configure the DUT as per table 1.1.
2) Connect one or more Clients to the DUT in the 5GHz band.
3) Start a packet capture on the operating band to monitor management frames.
4) Trigger a radar test signal on the center frequency of the DFS channel in which the DUT is operating.
5) Observe the DUT's behavior upon radar detection.

6) Verify that the DUT sends Channel Switch Announcement (CSA) Information Elements to associated clients.
7) Confirm that the DUT moves to a new channel within the allowed channel to move time.
8) Verify that connected clients follow the DUT to the new channel and reconnect successfully.
9) Validate regulatory timing requirements such as: Channel Availability Check (CAC), Channel Move Time, Non-Occupancy Period.
10) Repeat the test across multiple DFS channels and country configuration like US, UK, Japan, China, Korea etc.

Pass/Fail Criteria:

- The DFS test is considered **PASS** if the DUT detects radar, notifies clients via CSA, and switches to a valid channel within regulatory timing requirements. Failure to meet any DFS detection, notification, or timing requirement is considered **FAIL**.

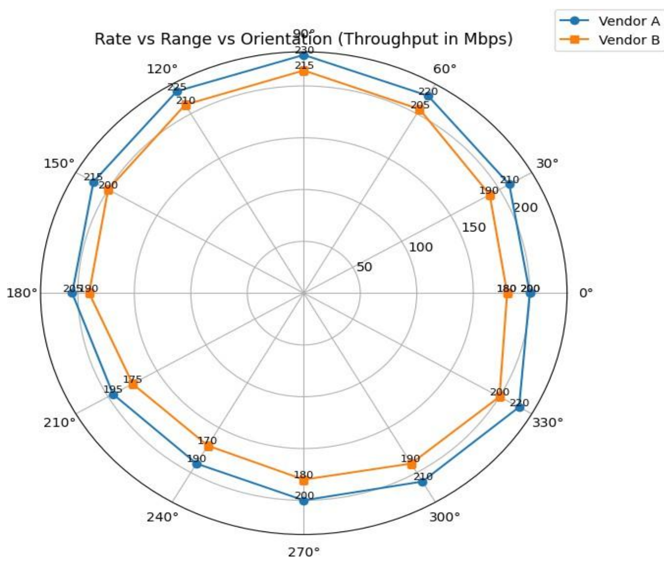
Rate vs Range vs Orientation Test

Objective:

To evaluate the DUT's throughput, PHY rate, and link behavior over distance and device orientation, where distance is emulated using attenuation and orientation is varied using rotation angles, to understand antenna performance, radiation pattern effects, and rate adaptation.

Observations:

- Throughput and PHY rates decrease consistently as attenuation increases, showing expected rate-vs-range behavior with dynamic rate adaptation.
- Performance varies with device orientation, with certain angles providing higher and more stable throughput, confirming antenna and spatial sensitivity.
- Connectivity is maintained across most rotations, with low packet loss at strong signals and degradation only near sensitivity limits.



Test Procedure:

1. Configure DUT and station for selected bands, bandwidth, and traffic type.
2. Start test at lowest attenuation and initial orientation (0°).
3. Run traffic and record throughput, RSSI, PHY rate, and latency.
4. Rotate DUT in defined angle steps (e.g., 0°–330°).
5. Repeat measurements for each orientation.
6. Increase attenuation in steps and repeat the full rotation cycle.
7. Log all metrics and generate performance plots.

Pass/Fail Criteria:

Pass if the DUT maintains stable connectivity with predictable throughput degradation, reasonable orientation variation, proper rate adaptation, and acceptable packet loss until near sensitivity limits else fail.

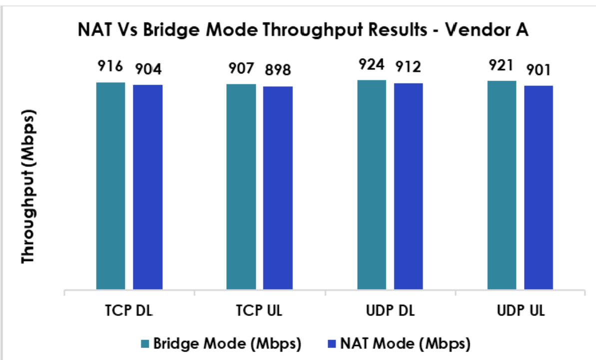
NAT vs Bridge Mode Test

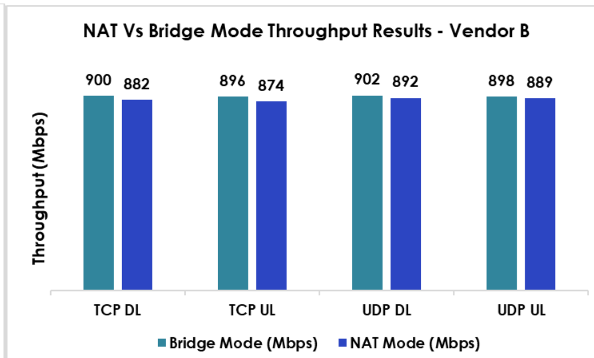
Objective:

The objective of this test is to verify the DUT's functionality in both NAT and Bridge modes. In NAT mode, this testing verifies that the DHCP Server configured in the DUT assigns IP addresses to clients and accesses the network while handling uplink and downlink traffic properly. In Bridge mode, this testing verifies that the clients receive IP details from the upstream network. In both modes, the testing ensures stable client connectivity and correct traffic flow using multiple clients.

Observations:

- Bridge mode consistently delivers higher throughput than NAT mode across all traffic types (TCP/UDP, UL/DL) for both Vendor-A and Vendor-B, due to reduced processing overhead.
- NAT mode shows a small but consistent throughput reduction, especially for uplink traffic, indicating the impact of NAT and routing functions on packet processing.
- UDP downlink achieves the highest throughput in both modes for both vendors, while TCP uplink shows comparatively lower throughput.





Test Procedure and Expected Result:

S No.	Test Case	Test Procedure	Expected Result
1	Verify the connection time and DHCP Lease Time in NAT Mode	1. Configure DUT as per Table 1.1 in NAT mode with the DHCP server enabled. 2. Set DHCP for lease time (e.g., 5 minutes). 3. Connect 10 clients and verify IP assignments. 4. Record connection time, IP, lease start and expiry. 5. Observe lease renewal at 50–70% lease time. 6. Allow lease expiry and monitor renewal behavior. 7. Capture DHCP packets if required.	1. Client connection time ≤ 5 seconds. All clients receive valid IPs. 2. Lease time matches configuration. 3. Leases renew before expiry without disruption. 4. No IP conflicts or client disconnects
2	Verify TCP Downlink throughput performance in NAT mode on 2.4 GHz band with multiple clients	1. Configure DUT as per Table 1.1 in NAT mode. 2. Connect 10 clients on 2.4 GHz band. Run TCP downlink traffic for 5 minutes. 3. Record per-client and aggregate throughput.	1. All clients reach the gateway. 2. Achieved throughput > 70% of theoretical PHY rate.

NOTE: Repeat Test Cases for other traffic types such as TCP Uplink, UDP Uplink, and Downlink. Repeat the testcases with the DUT configured in Bridge mode.

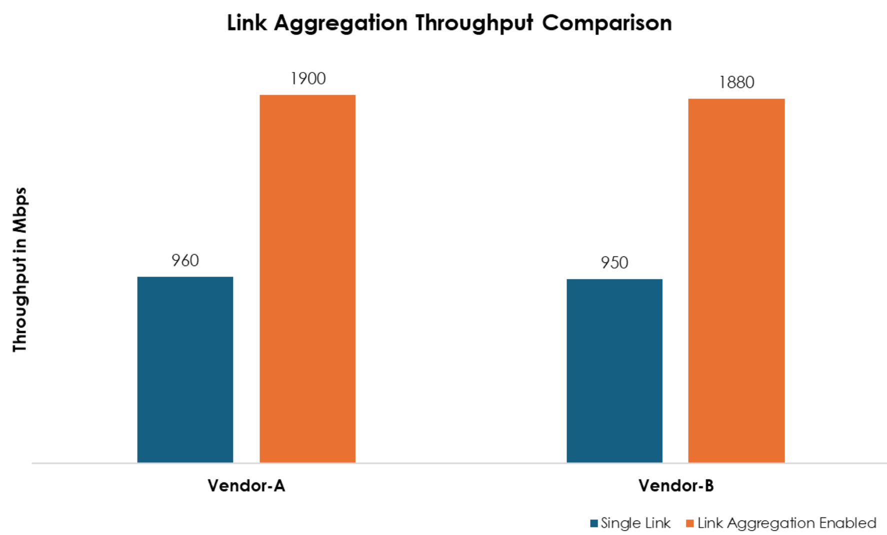
Link Aggregation Test

Objective:

The objective of the Link Aggregation Test is to verify that the DUT correctly supports link aggregation by combining multiple physical Ethernet links into a single logical interface to improve throughput, redundancy, and link reliability.

Observations:

- Throughput with link aggregation enabled is significantly higher compared to single-link operation.
- Aggregate throughput scales as expected when multiple links are active, indicating effective load distribution.
- The results confirm proper functioning of link aggregation in improving uplink/downlink capacity.



Test Procedure:

1. Configure the DUT with a single active Ethernet uplink and establish network connectivity.
2. Measure and record baseline throughput using the single active link.
3. Enable link aggregation on the DUT and upstream switch.
4. Connect multiple Ethernet links and ensure successful aggregation.
5. Generate traffic to saturate the aggregated interface.
6. Measure and record aggregate throughput.

7. Compare results against single-link performance.

Pass/Fail Criteria:

- Aggregate throughput with link aggregation enabled should be significantly higher than single-link throughput.

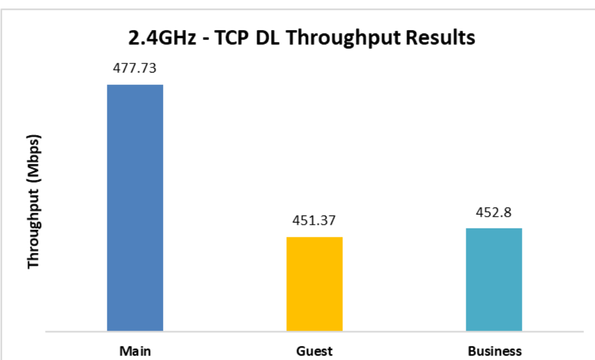
Main/Guest/Business SSIDs Performance

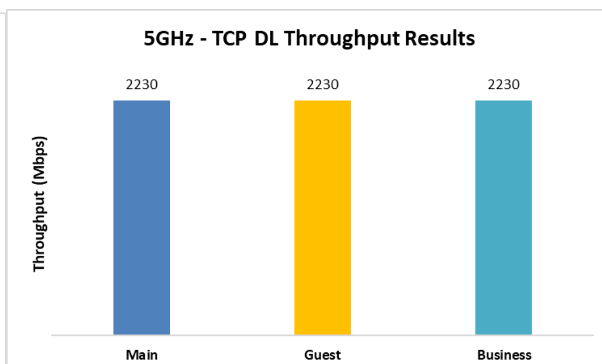
Objective:

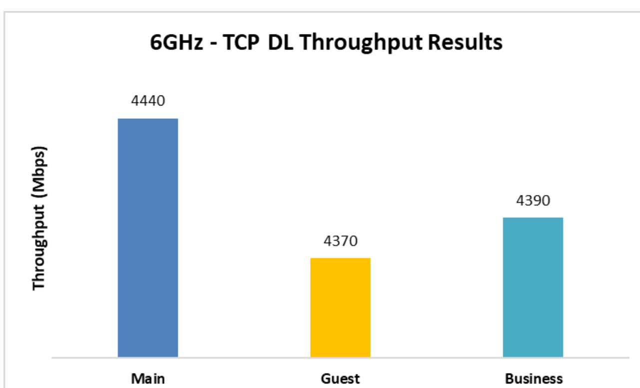
The objective of this test is to verify the throughput performance of the DUT across different SSIDs (Main, Guest, Business). The test ensures that each SSID delivers expected performance levels independently, and that SSID configuration differences (isolation, rate limits, VLAN mapping, security modes, etc.) do not negatively impact throughput.

Observations:

- Throughput remains consistent across Main, Guest, and Business SSIDs for all bands, indicating effective SSID isolation and efficient traffic handling at the AP, with no measurable contention or scheduling overhead introduced by multiple SSID configurations.







Test Procedure:

1. Configure the DUT with three SSIDs: Main SSID, Guest SSID, and Business SSID, using

their respective security and network settings.
2. Associate a single client with the Main SSID to one of the DUT's supported frequency bands.
3. Measure the downlink TCP throughput to the STA with an intended load equal to PHY Rate, for a test duration of 2 minutes.
4. Record throughput results.
5. Repeat the test across all supported bands, different traffic types, and directions.
6. Repeat the test across Guest and Business SSIDs.

Pass/Fail Criteria:

- The client should successfully connect all three SSIDs with the correct IP assignment.
- The achieved throughput must be 70% of the maximum theoretical PHY Rate supported by DUT for all SSIDs.

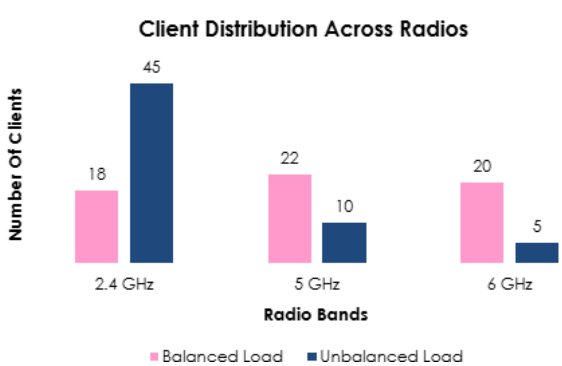
Load Balancing

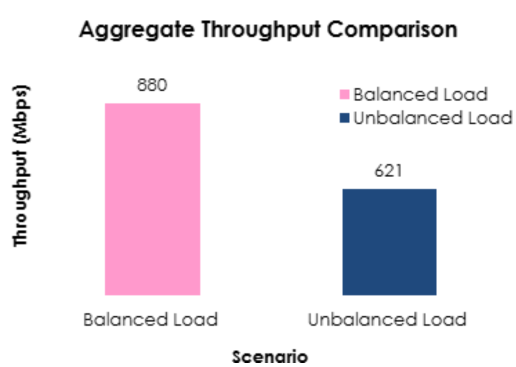
Objective:

The objective of the Load Balancing Test is to verify that the DUT distributes client associations intelligently across available radios or APs based on client count, RSSI, channel utilization, and radio capacity. This test ensures that DUT prevents overcrowding a single AP or radio, redirects clients toward less-loaded resources, and maintains overall network performance and fairness in multi-AP or multi-radio environments.

Observations:

- DUT effectively balanced client associations across radios and APs, preventing congestion and ensuring optimal resource utilization under varying load conditions.
- Load balancing enabled higher aggregate throughput and more stable per-client performance compared to unbalanced association scenarios.





Test Procedure:

1. Configure the DUT as per Table 1.1.
2. Establish client associations at strong RSSI levels (≈ -40 dBm).
3. Increase client density and traffic load on selected radios or APs.
4. Observe association steering behavior and compare throughput with load balancing enabled and disabled.

Pass/Fail Criteria:

- Pass if client distribution is balanced across radios/APs and aggregate throughput improves load balancing enabled; otherwise Fail.

Medium Stress

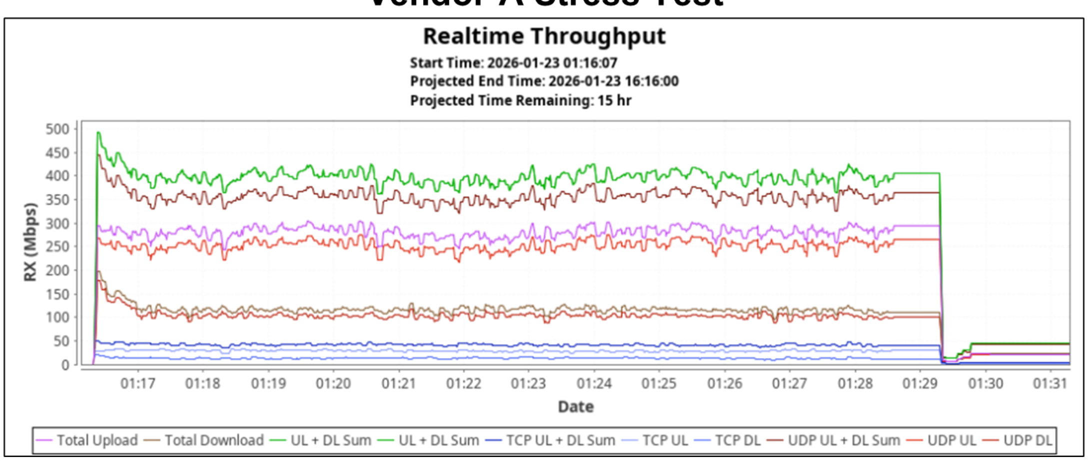
Objective:

The objective of the Medium Stress Test is to evaluate how the DUT performs when 30 - 40 clients are connected and run uplink, downlink, or bi-directional traffic. This test verifies that the DUT maintains stable connectivity, consistent throughput, and acceptable resource usage (Memory, Thermal, CPU) under medium network load conditions.

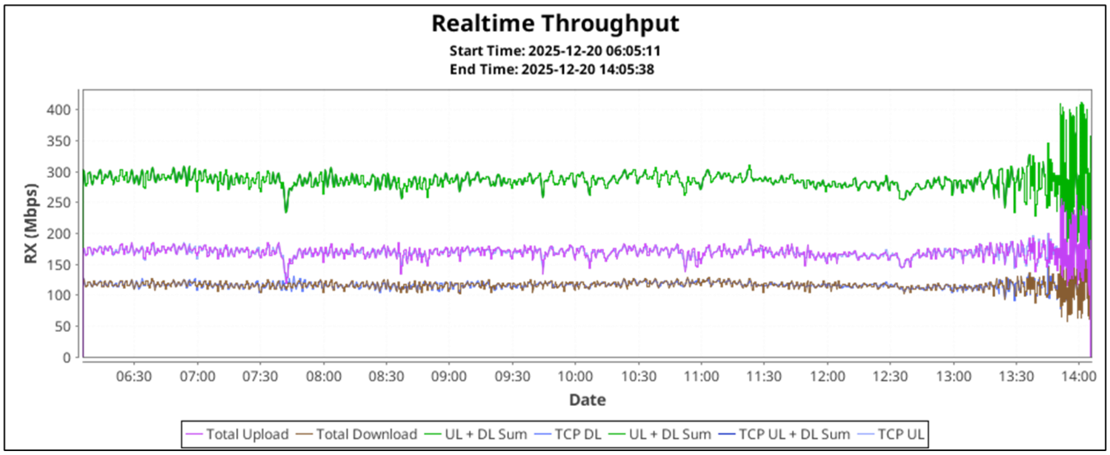
Observations:

- Vendor-A: A sharp drop in throughput was observed when ~90% of clients disconnected and reconnected simultaneously; throughput did not fully recover to pre-drop levels during the test window.
- Vendor-B: Throughput remained stable throughout the test, with no client disconnections, AP reboots, or crashes observed.
- Overall, Vendor-B demonstrated better stability under medium stress, while Vendor-A showed sensitivity to large-scale client re-association events.

Vendor-A Stress Test



Vendor-B Stress Test



Test Procedure:

1. Configure the DUT as per table 1.1.
2. Connect a total of 30 – 40 clients across the DUT's available bands.
3. Apply a medium intended load of 1Mbps/ 2.4GHz client, 2 Mbps/ 5GHz client, 4Mbps/6GHz client (UL, DL, Bi-directional or mixed) for 12 hours.
4. Monitor client connectivity, system stability, and throughput throughout the test duration.
5. Repeat the test for different traffic types, i.e., TCP, and UDP.

Pass/Fail Criteria:

- The DUT should maintain stable connectivity and deliver consistent throughput under medium load conditions.
- No client drops, performance degradation, or DUT crashes or reboots should be observed.

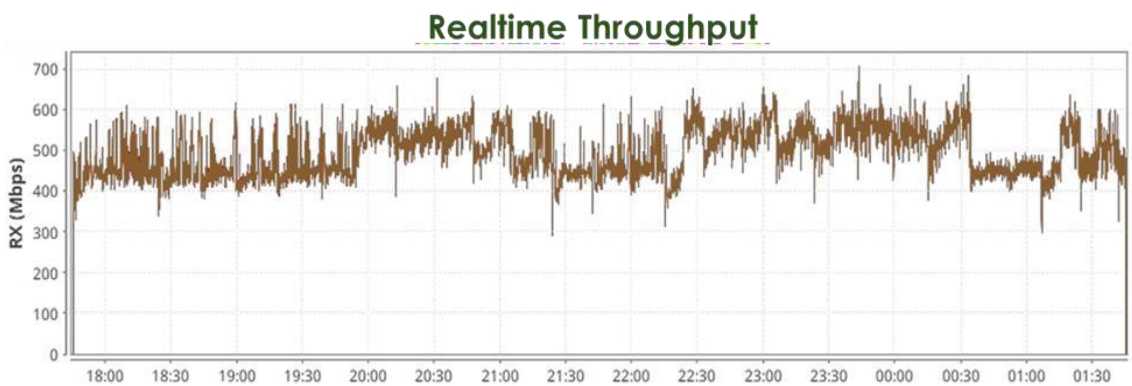
Wi-Fi Client Reset Test with Traffic

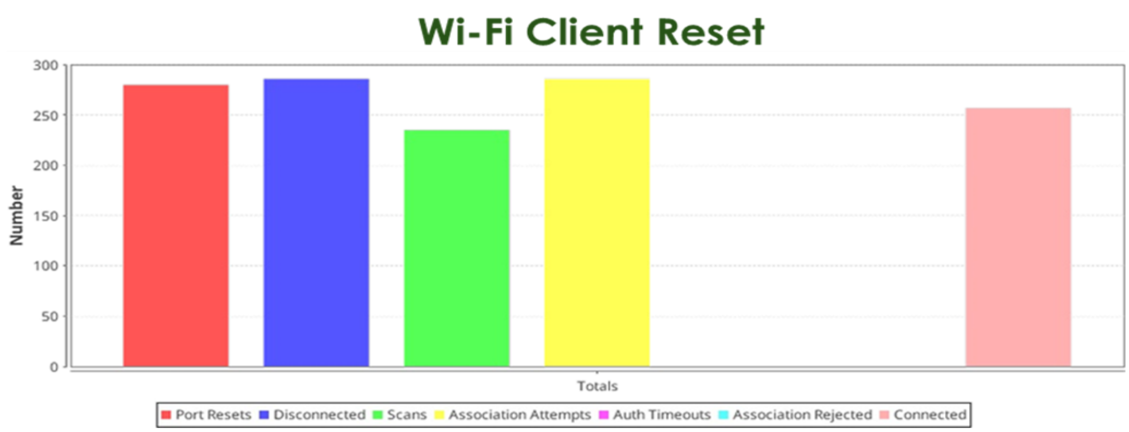
Objective:

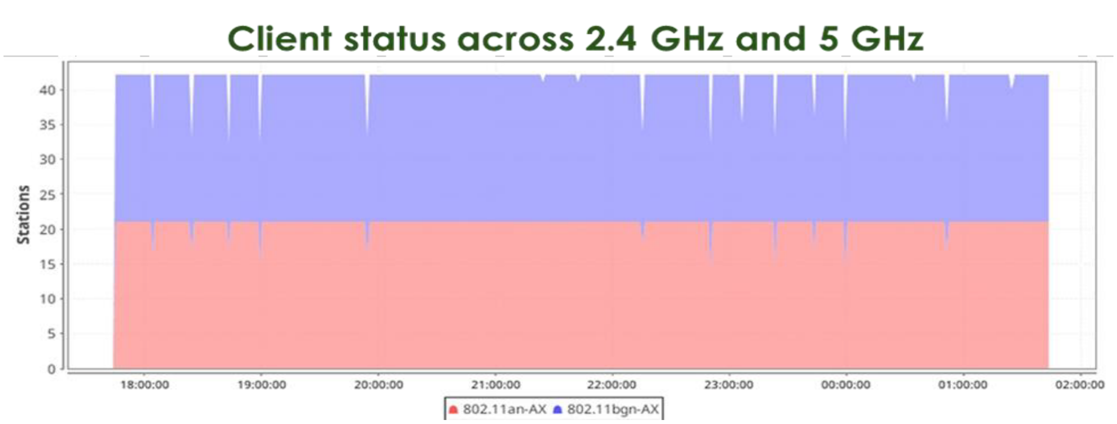
The objective of this Wi-Fi reset test with traffic is to simulate a real-world environment where multiple clients repeatedly disconnect and reconnect while running mixed uplink and downlink traffic. This test helps evaluate how effectively the DUT handles continuous client resets during active traffic and identifies potential issues in association handling, session stability, and overall AP performance under dynamic client behavior.

Observations:

- In this test (Test duration is 8 hours) we have 42 clients connected to the Access Point and run UDP downlink traffic with maximum intended load and randomly 10 clients will disconnect and reconnect with a new MAC address for every 10 to 15 minutes.
- We can see the Real time throughput and the client status throughout the test across the 2.4GHz and 5GHz band.







Test Procedure:

1. Configure the DUT as per table 1.1.
2. Associate multiple Wi-Fi stations to the SSID of DUT.
3. Run continuous TCP or UDP traffic between each station and upstream at a required intended load.
4. While traffic is running, reset one station by forcing a disconnect and allowing it to re-associate. Repeat the reset multiple times at random intervals.
5. Monitor throughput, packet loss, and connectivity for all stations throughout the reset process.
6. Optionally reset additional stations sequentially or concurrently while traffic continues.
7. Record client re-association time, throughput behaviour, and DUT stability.
8. Repeat the test for different DUT configurations or frequency bands as required.

Pass/Fail Criteria:

- Pass if non-reset stations maintain stable traffic throughput during client reset events.
- Pass if reset clients successfully re-associate and resume traffic within an acceptable time.
- Pass if the DUT remains stable without crashes or major performance degradation.

Comprehensive Test Suite

Tx Power Test in Different Regulations

Objective:

The objective of this test is to verify that DUT correctly enforces region-specific transmit power limits based on the configured regulatory domain. This test ensures that transmitting power levels for 2.4 GHz, 5 GHz, and 6 GHz bands remain within country-specific regulatory constraints while maintaining accurate power reporting and stable client connectivity, which is critical for regulatory compliance and predictable RF performance across global deployments.

Observations:

- Both vendors remained compliant with region-specific regulatory transmit power limits across all tested frequency bands and regions.
- Vendor A demonstrated more consistent transmit power behavior, with closer alignment between configured and measured output across bands, bandwidths, and channels, while Vendor B operated at slightly more conservative power levels at higher frequencies.

- Overall, Vendor A showed tighter power accuracy and stability, whereas Vendor B stayed within acceptable regulatory compliance margins.

Regulatory Domain	Band	Configured Tx Power (dBm)	Vendor A DUT side Tx Power (dBm)	Vendor B DUT side Tx Power (dBm)	Vendor A Controller–Client Difference (dB)	Vendor B Controller–Client Difference (dB)
US	2.4 GHz	20	20	19	2.0	2.5
US	5 GHz	23	23	22	2.0	2.5
US	6 GHz	28	28	26	2.0	3.0
UK	2.4 GHz	20	20	19	1.8	2.2
UK	5 GHz	23	23	22	1.5	2.0
UK	6 GHz	26	26	25	2.0	2.5
India	2.4 GHz	20	20	19	1.5	2.0
India	5 GHz	22	22	21	1.7	2.2
India	6 GHz	26	26	25	2.0	2.5
Japan	2.4 GHz	20	20	19	1.6	2.1
Japan	5 GHz	22	22	21	1.8	2.3
Japan	6 GHz	26	26	25	2.0	2.6

Test Procedure:

- Configure the DUT with the required regulatory domain (US, UK, India, Japan) as per the test requirement and disable dynamic power control features.
- Set Tx power incrementally across supported ranges on 2.4 GHz, 5 GHz, and 6 GHz radios and measure conducted output power per band, channel, and bandwidth.
- Capture Tx power values from DUT/controller logs and client-side measurements after accounting for cable path loss.
- Compute Controller–Client Difference as the difference between client-side measurements and DUT TX power observed from the logs.
- Repeat the test with different channel and bandwidth combinations.
- Compare measured values against configured limits and regulatory requirements.

Pass/Fail Criteria:

- Pass if measured transmit power across all bands and regulatory domains remains within configured regional limits and the controller-to-client power difference is < 6 dBm; otherwise Fail.

Multi BSSID and VLAN Segmentation

Objective:

The objective of this test is to verify that the DUT correctly enforces VLAN-based network segmentation across multiple SSIDs, ensuring that clients associated with each SSID are placed into their designated VLANs. This test validates strict Layer-2 and Layer-3 traffic isolation between SSIDs while maintaining correct IP addressing and upstream connectivity, which is critical for securing separation of enterprise, guest, and other user networks.

Observations:

1. The DUT consistently enforced correct SSID-to-VLAN mapping, with clients receiving appropriate VLAN tags, IP addresses, and gateway assignments.
2. Layer-2 and Layer-3 traffic isolation was maintained across all SSIDs, with no broadcast, multicast, or unicast leakage observed between VLANs.

Test Procedure:

1. Configure multiple SSIDs on the DUT, each mapped to a unique VLAN ID with corresponding DHCP scopes.
2. Associate clients with each SSID and verify VLAN tagging, IP assignment, and default gateway correctness.
3. Generate intra- and inter-VLAN traffic to validate isolation and forwarding behavior.
4. Capture traffic and routing behavior to confirm absence of cross-VLAN leakage.

Pass/Fail Criteria:

- Pass each SSID map to the correct VLAN with proper IP and gateway assignment and all inter-SSID/VLAN traffic remains isolated; otherwise Fail.

PMK Caching

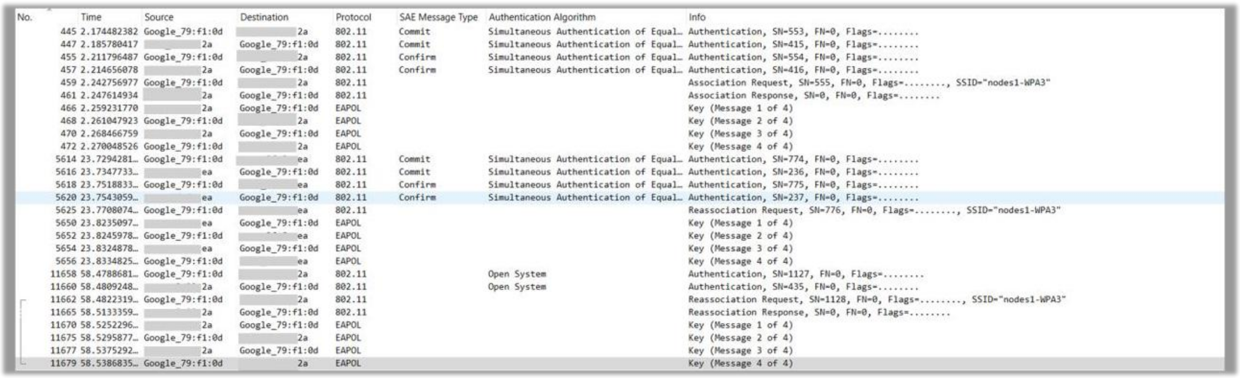
Objective:

The objective of this test is to verify that PMK caching functions correctly with WPA3-Personal security, enabling a previously authenticated client to reconnect to the same

SSID without performing a full SAE authentication exchange. This test ensures faster reconnection times while maintaining secure and stable connectivity, which is critical for user experience during brief disconnections and roaming scenarios.

Observations:

- During reconnection, the client reused the cached PMK and did not perform a full SAE authentication exchange and instead used Open System authentication, as confirmed by frame analysis.
- Reconnection time was significantly shorter than the initial connection, indicating effective PMK caching without impacting connection stability.



No.	Time	Source	Destination	Protocol	SAE Message Type	Authentication Algorithm	Info
445	2.174482382	Google_79:f1:0d	2a	802.11	Commit	Simultaneous Authentication of Equal…	Authentication, SN=553, FN=0, Flags=........
447	2.185780417	2a	Google_79:f1:0d	802.11	Commit	Simultaneous Authentication of Equal…	Authentication, SN=415, FN=0, Flags=........
455	2.211796487	Google_79:f1:0d	2a	802.11	Confirm	Simultaneous Authentication of Equal…	Authentication, SN=554, FN=0, Flags=........
457	2.214656078	2a	Google_79:f1:0d	802.11	Confirm	Simultaneous Authentication of Equal…	Authentication, SN=416, FN=0, Flags=........
459	2.242756977	Google_79:f1:0d	2a	802.11			Association Request, SN=555, FN=0, Flags=........, SSID="nodes1-WPA3"
461	2.247614934	2a	Google_79:f1:0d	802.11			Association Response, SN=0, FN=0, Flags=........
466	2.259231770	2a	Google_79:f1:0d	EAPOL			Key (Message 1 of 4)
468	2.261047923	Google_79:f1:0d	2a	EAPOL			Key (Message 2 of 4)
470	2.268466759	2a	Google_79:f1:0d	EAPOL			Key (Message 3 of 4)
472	2.270048526	Google_79:f1:0d	2a	EAPOL			Key (Message 4 of 4)
5614	23.7294281…	Google_79:f1:0d	ea	802.11	Commit	Simultaneous Authentication of Equal…	Authentication, SN=774, FN=0, Flags=........
5616	23.7347733…	ea	Google_79:f1:0d	802.11	Commit	Simultaneous Authentication of Equal…	Authentication, SN=236, FN=0, Flags=........
5618	23.7518833…	Google_79:f1:0d	ea	802.11	Confirm	Simultaneous Authentication of Equal…	Authentication, SN=775, FN=0, Flags=........
5620	23.7543059…	ea	Google_79:f1:0d	802.11	Confirm	Simultaneous Authentication of Equal…	Authentication, SN=237, FN=0, Flags=........
5625	23.7708074…	Google_79:f1:0d	ea	802.11			Reassociation Request, SN=776, FN=0, Flags=........, SSID="nodes1-WPA3"
5650	23.8235097…	ea	Google_79:f1:0d	EAPOL			Key (Message 1 of 4)
5652	23.8245978…	Google_79:f1:0d	ea	EAPOL			Key (Message 2 of 4)
5654	23.8324878…	ea	Google_79:f1:0d	EAPOL			Key (Message 3 of 4)
5656	23.8334825…	Google_79:f1:0d	ea	EAPOL			Key (Message 4 of 4)
11658	58.4788681…	Google_79:f1:0d	2a	802.11		Open System	Authentication, SN=1127, FN=0, Flags=........
11660	58.4809248…	2a	Google_79:f1:0d	802.11		Open System	Authentication, SN=435, FN=0, Flags=........
11662	58.4822319…	Google_79:f1:0d	2a	802.11			Reassociation Request, SN=1128, FN=0, Flags=........, SSID="nodes1-WPA3"
11665	58.5133359…	2a	Google_79:f1:0d	802.11			Reassociation Response, SN=0, FN=0, Flags=........
11670	58.5252296…	2a	Google_79:f1:0d	EAPOL			Key (Message 1 of 4)
11675	58.5295877…	Google_79:f1:0d	2a	EAPOL			Key (Message 2 of 4)
11677	58.5375292…	2a	Google_79:f1:0d	EAPOL			Key (Message 3 of 4)
11679	58.5386835…	Google_79:f1:0d	2a	EAPOL			Key (Message 4 of 4)

Test Procedure:

1. Configure the DUT with a WPA3-Personal SSID
2. Connect a client to the SSID for the first time and capture authentication and association frames.
3. Disconnect the client or toggle Wi-Fi OFF briefly, then reconnect to the same SSID.
4. Compare authentication exchanges and connection times between initial and cached reconnections.

Pass/Fail Criteria:

Pass if the client reconnects using cached PMK without repeating full SAE authentication and achieves a noticeably faster reconnection time than the initial association; otherwise Fail.

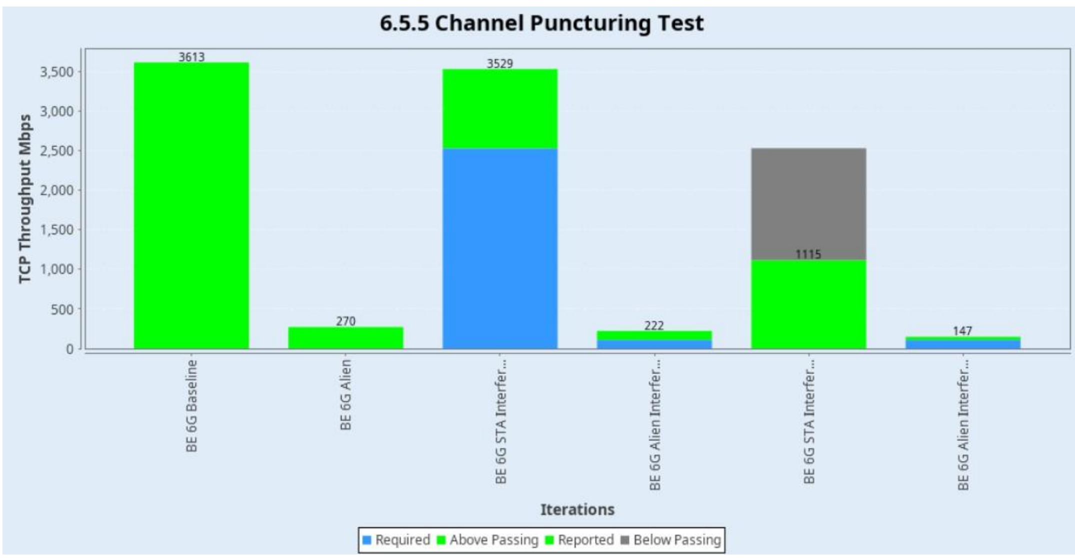
Preamble Puncturing

Objective:

The objective of this test is to determine whether Preamble Puncturing allows Wi-Fi Access Points to increase spectral efficiency by ignoring transmissions on sub channels that are affected by interference and making use of the rest of the occupied spectrum.

Observations:

- In the baseline (no interference) scenario, the DUT achieved a peak TCP throughput of ~3613 Mbps, establishing the reference DUT peak throughput.
- With preamble puncturing disabled and co-channel interference present, throughput dropped sharply to ~1115 Mbps (~31% of peak) and further down to ~270 Mbps / ~222 Mbps in alien AP interference cases, indicating severe spectrum blockage and inefficient channel utilization.
- After enabling preamble puncturing, throughput improved significantly under interference, reaching ~3529 Mbps (~97% of baseline) in the 6 GHz STA interference case, clearly exceeding the 70% pass threshold.
- These results demonstrate that preamble puncturing effectively isolates interfered sub-channels and allows DUT to continue high-rate transmission on available spectrum, validating correct puncturing behavior and spectral efficiency gains.



Test Procedure:

1. Configure the DUT as per table 1.1.
2. Connect an 11be supported client to the DUT.
3. Disable Preamble Puncturing and run peak throughput with the client in the bandwidth configured on the AP (should be 80MHz or above) and mark this as DUT peak throughput.
4. Now introduce a VAP/another AP which is operating on 20MHz/40MHz/80MHz to create interference.
5. Now run the peak throughput test on DUT and record the throughput and note this value as throughput puncturing disabled.
6. Now enable the preamble puncturing feature on DUT and run peak throughput test along with the interfering AP running traffic simultaneously. Record the

throughput value as throughput puncturing enabled.

Pass/Fail Criteria:

- For 5 GHz – 80 MHz Channel Width:
  PASS if: throughput puncturing disabled ≥ 40% of DUT peak throughput, and throughput puncturing enabled ≥ 70% of DUT peak throughput. Otherwise Fail.
- For 6 GHz – 320 MHz Channel Width:
  PASS if: throughput puncturing disabled ≥ 40% of DUT peak throughput, and throughput puncturing enabled ≥ 70% of DUT peak throughput. Otherwise Fail.

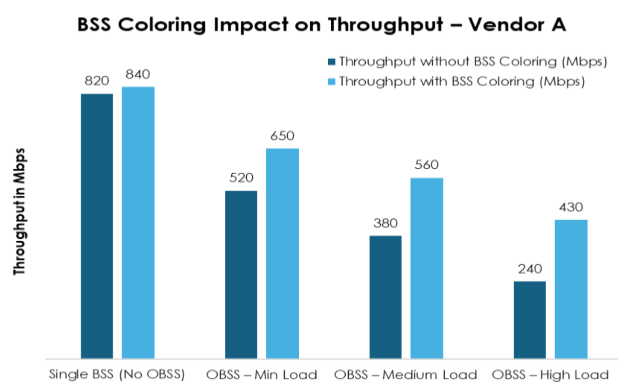
BSS Coloring Test

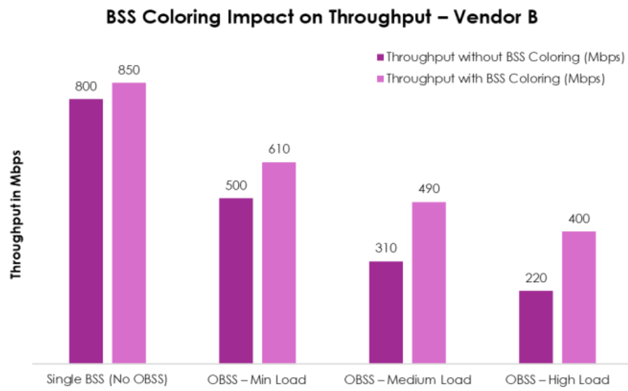
Objective:

The objective of this test is to validate the effectiveness of BSS Coloring in reducing co-channel interference in overlapping BSS (OBSS) environments. The test verifies whether enabling BSS Coloring improves spatial reuse and overall throughput when multiple neighboring BSS operates on the same channel.

Observations:

- Enabling BSS Coloring consistently improves throughput across all interference scenarios compared to when it is disabled.
- The throughput gain from BSS Coloring becomes more pronounced as OBSS density increases, indicating effective spatial reuse.
- In low-interference conditions, performance remains comparable, showing that BSS Coloring does not negatively impact single-BSS operation.





Test Procedure:

1. Configure two Access Points to operate on the same channel and bandwidth. Have BSS coloring disabled on both the APs.
2. Ensure that there is enough overlap between the range coverage of both APs (RSSI should be strong enough so that one of the APs defer transmission in CCA due to high RSSI of other APs transmission)
3. Create BE STAs equally on both the APs and run peak throughput tests for 5minutes.
4. Note the achieved throughput values for both the APs.
5. Perform the above three steps for 20Mhz, 40MHz, 80MHz, and 160MHz.
6. Repeat the same test case with BSS coloring enabled.

Pass/Fail Criteria:

The test is considered PASS if throughput with BSS Coloring enabled is equal to or higher than throughput with BSS Coloring disabled in OBSS scenarios; otherwise, the test is FAIL.

MRU (Multi-Resource Unit) Test

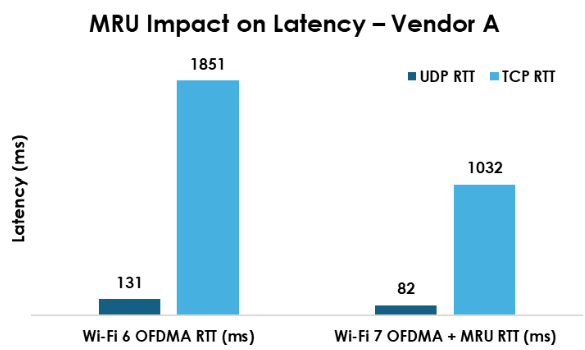
Objective:

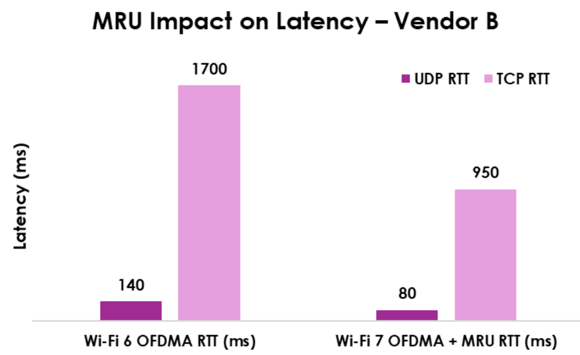
The objective of this test is to evaluate and compare latency performance between traditional Wi-Fi 6 OFDMA and Wi-Fi 7 OFDMA enhanced with Multi-Resource Unit (MRU) allocation. The test aims to determine whether MRU improves packet scheduling efficiency and reduces round-trip time (RTT) for both UDP and TCP traffic under identical network conditions.

Observations:

- MRU-enabled operation shows a significant reduction in round-trip latency compared to standard OFDMA for both UDP and TCP traffic.

- Latency improvement is more pronounced for TCP traffic, indicating better handling of bidirectional flows and reduced scheduling delays with MRU.
- The consistent lower RTT values with MRU demonstrate more efficient packet scheduling and faster turnaround under identical network conditions.





Test Procedure:

1. Configure the DUT for Wi-Fi 6 OFDMA operation and associate two client stations.
2. Generate UDP and TCP traffic and measure round-trip time (RTT).
3. Reconfigure the DUT for Wi-Fi 7 OFDMA with MRU enabled.
4. Verify MRU allocation using packet capture and trigger frame analysis.
5. Repeat UDP and TCP RTT measurements under identical traffic conditions.
6. Record and compare latency results between the two configurations.

Pass/Fail Criteria:

The test is considered **PASS** if RTT with Wi-Fi 7 OFDMA + MRU is lower than RTT with Wi-Fi 6 OFDMA for both UDP and TCP traffic; otherwise, the test is **FAIL**.

Mesh Functionality- Mesh Discovery, Peering, Path Selection

Objective:

The objective of this test is to validate the core mesh networking functions, including mesh discovery, mesh peering establishment, and path selection. The test ensures that mesh nodes can automatically discover neighboring nodes, establish stable peering relationships, and select optimal data paths for traffic forwarding within a mesh topology.

Observations:

- Mesh nodes successfully discovered neighboring mesh nodes within the expected time.

- Stable mesh peering relationships were established without repeated retries or failures.
- Path selection logic correctly identified and maintained the optimal forwarding path. No mesh instability or path shifting was observed during the test duration.

  SAE Commit and confirm capture.

```
> Frame 2513: 182 bytes on wire (1456 bits), 182 bytes captured (1456 bits)
> Radiotap Header v0, Length 54
> 802.11 radio information
> IEEE 802.11 Authentication Flags: ........
v IEEE 802.11 Wireless Management
  v Fixed parameters (104 bytes)
      Authentication Algorithm: Simultaneous Authentication of Equals (SAE) (3)
      Authentication SEQ: 0x0001
      Status code: Successful (0x0000)
      SAE Message Type: Commit (1)
      Group Id: 256-bit random ECP group (19)
      Scalar: 3854dfd0290d7db51ac6b39689c24d7e4e8473907c82cd2242710c4e6ab053a2
      Finite Field Element: d287b3cde89ef099b335a590c024cffa1c9ddf5f133a66bdc1e7a21e967e91846af039f2
```

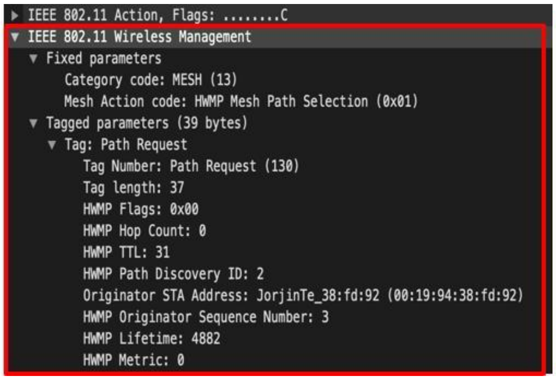
- Mesh Peering Open, Confirm and Close captures.

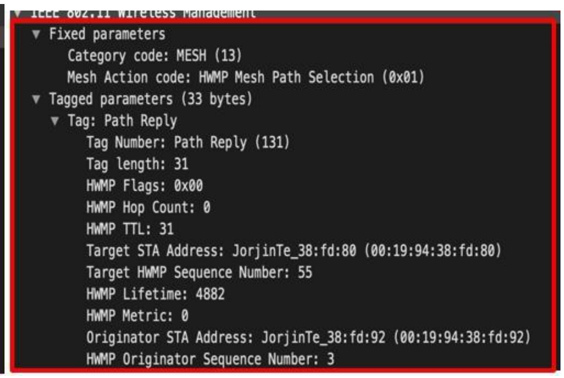
```
EE 802.11 Wireless Management
 Fixed parameters
   Category code: Self-protected (15)
   Self-protected Action code: Mesh Peering Open (0x01)
 > Capabilities Information: 0x0010
 Tagged parameters (313 bytes)
 > Tag: Supported Rates 6(B), 9, 12(B), 18, 24(B), 36, 48, 54, [Mbit
 > Tag: RSN Information
 > Tag: Mesh ID: 7d880e
 > Tag: Mesh Configuration
 > Tag: Vendor Specific: eero inc.
 v Tag: Mesh Peering Management
     Tag Number: Mesh Peering Management (117)
     Tag length: 20
     Mesh Peering Protocol ID: Authenticated mesh peering exchange
     Local Link ID: 0x9e0d
     PMKID: 8c047b9b522b5f61aef3d86a1556ec7d
```

```
Fixed parameters
  Category code: Self-protected (15)
  Self-protected Action code: Mesh Peering Confirm (0x02)
> Capabilities Information: 0x0010
  ..00 0000 0000 0001 = Association ID: 0x0001
Tagged parameters (315 bytes)
> Tag: Supported Rates 6(B), 9, 12(B), 18, 24(B), 36, 48,
> Tag: RSN Information
> Tag: Mesh ID: 7d880e
> Tag: Mesh Configuration
> Tag: Vendor Specific: eero inc.
v Tag: Mesh Peering Management
    Tag Number: Mesh Peering Management (117)
    Tag length: 22
    Mesh Peering Protocol ID: Authenticated mesh peering
    Local Link ID: 0x9e0d
    Peer Link ID: 0x8f59
```

```
IEEE 802.11 Wireless Management
v Fixed parameters
    Category code: Self-protected (15)
    Self-protected Action code: Mesh Peering Close (0x03)
v Tagged parameters (149 bytes)
  v Tag: Mesh ID: 7dd69
      Tag Number: Mesh ID (114)
      Tag length: 5
      Mesh ID: 7dd69
  v Tag: Mesh Peering Management
```

PREQ, PREP captures





Test Procedure:

1. Power on all mesh nodes and configure them with mesh functionality enabled.
2. Allow mesh nodes to perform automatic discovery of neighboring nodes.
3. Establish mesh peering between discovered nodes.
4. Initiate traffic across the mesh and observe path selection behavior.
5. Record discovery time, peer stability, and selected data paths.
6. Monitor the mesh for stability over a sustained duration.

Pass/Fail Criteria:

The test is considered PASS if all mesh nodes successfully discover peers, establish stable peering, and maintain correct path selection without instability; otherwise, the test is failed.

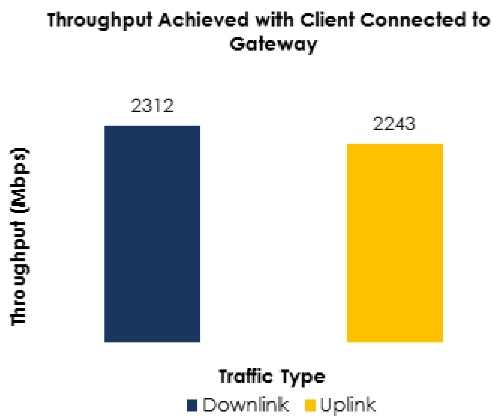
Wired Performance Among Mesh APs

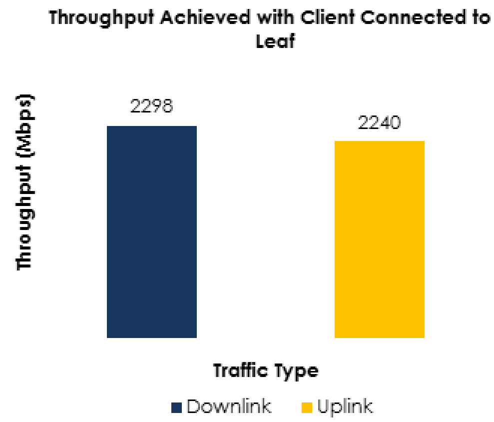
Objective:

The objective of this test is to evaluate the maximum achievable throughput and overall stability of the DUT in a wired - wireless mesh topology where a backhaul is established between the gateway and leaf nodes. The test measures peak uplink and downlink throughput when a wireless client is connected to the gateway and when connected to the leaf, under ideal wired backhaul conditions, to ensure that the DUT can deliver the expected performance independent of Wi-Fi limitations.

Observations:

- Both Gateway- and Leaf-connected clients achieved consistently high uplink and downlink throughput (>2.2 Gbps), indicating efficient utilization of wired backhaul links.
- Throughput symmetry between UL and DL and minimal variance across nodes confirms absence of wired bottlenecks in the mesh topology.





Test Procedure:

- Establish wired mesh topology with Gateway and Leaf APs connected via 10G and 5G Ethernet based on the AP supported port capability.
- Connect a client to the Gateway AP and measure uplink and downlink throughput.
- Connect a client to the Leaf AP and measure uplink and downlink throughput.
- Record signal levels and validate throughput consistency across nodes.

Pass/Fail Criteria:

- Pass if both Gateway and Leaf nodes sustain consistently high UL/DL throughput, with Leaf node throughput ≥ 90% of Gateway throughput and no significant performance degradation across the wired mesh backhaul; otherwise Fail.

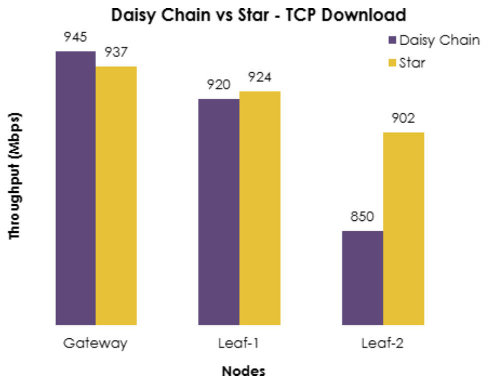
Mesh Roaming with different topologies like Star and Daisy chain.

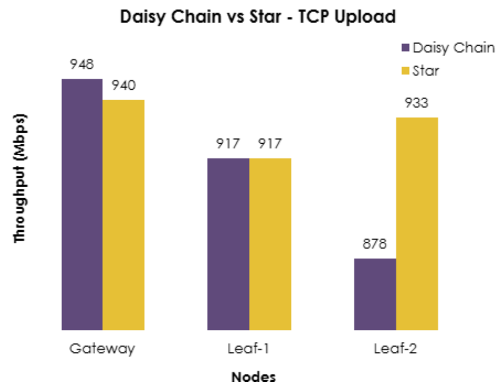
Objective:

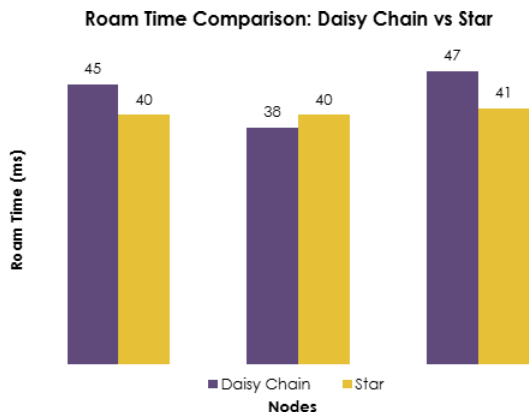
The objective of this test is to form performance and end-to-end throughput behavior across mesh APs deployed in Star and Daisy Chain topologies. This test ensures that roaming events occur with minimal service disruption while maintaining stable throughput, acceptable latency, and low packet loss across gateway and leaf nodes, which is critical for real-world multi-node mesh deployments.

Observations:

- The Star topology consistently delivered higher per-node throughput than Daisy Chain for both TCP DL and UL directions.
- Roam times and latency were lower and more consistent in the Star topology, particularly at Leaf-2, while Daisy Chain showed increased roam times and latency as hop depth increased.







Test Procedure:

1. Configure the mesh network in Daisy Chain and Star topologies as per the test scenario.
2. Run TCP uplink and downlink traffic while a client roams across Gateway, Leaf-1, and Leaf-2 nodes.
3. Capture throughput, RSSI before/after roaming, packet loss, latency, and roam time for each node.
4. Repeat the test for both TCP DL and TCP UL scenarios.
5. Compare per-node and aggregate performance between Star and Daisy Chain topologies.

Pass / Fail Criteria

- Pass if roaming across Gateway and Leaf nodes in both Star and Daisy Chain topologies maintains stable TCP UL/DL throughput, low packet loss, and acceptable roam times(100ms), with Star topology demonstrating equal or better aggregate performance than Daisy Chain; otherwise Fail.

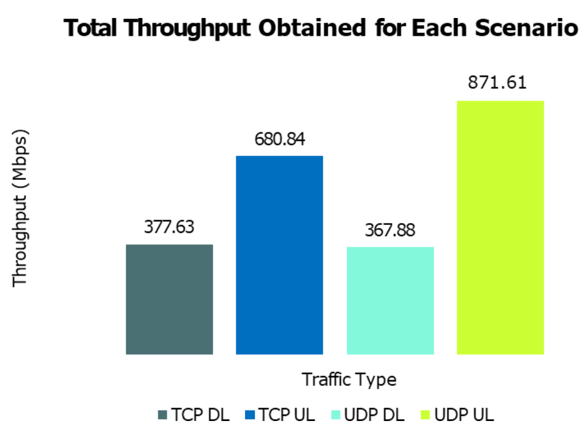
Scale Test with High Client Count and Variable Load patterns.

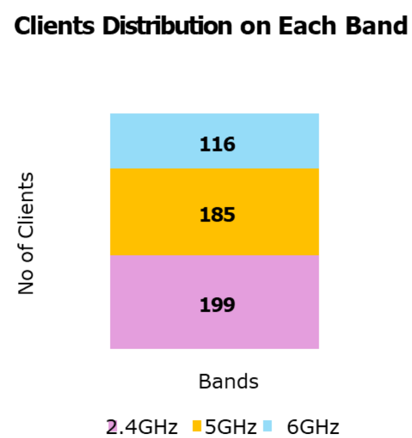
Objective:

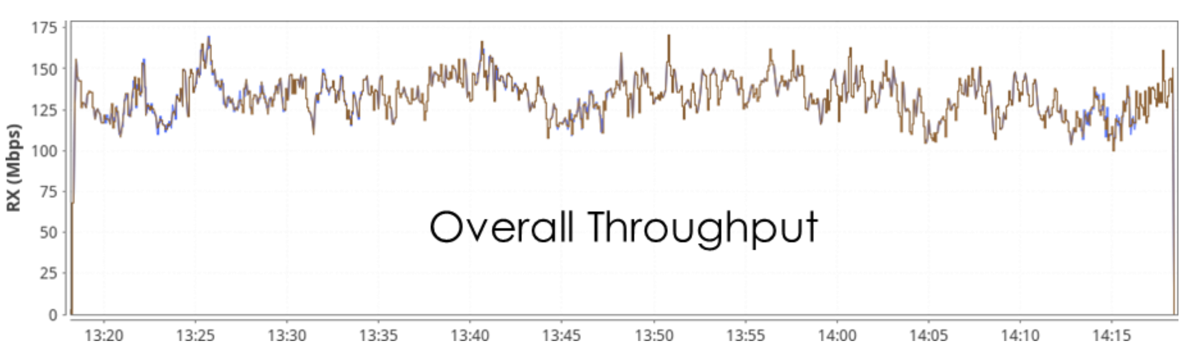
The objective of this test is to evaluate the stability, scalability, and performance of the Wi-Fi system when supporting many concurrently associated clients (500+). The test validates the ability of the DUT to handle increasing client density under different traffic load patterns while maintaining acceptable aggregate throughput and stable operation.

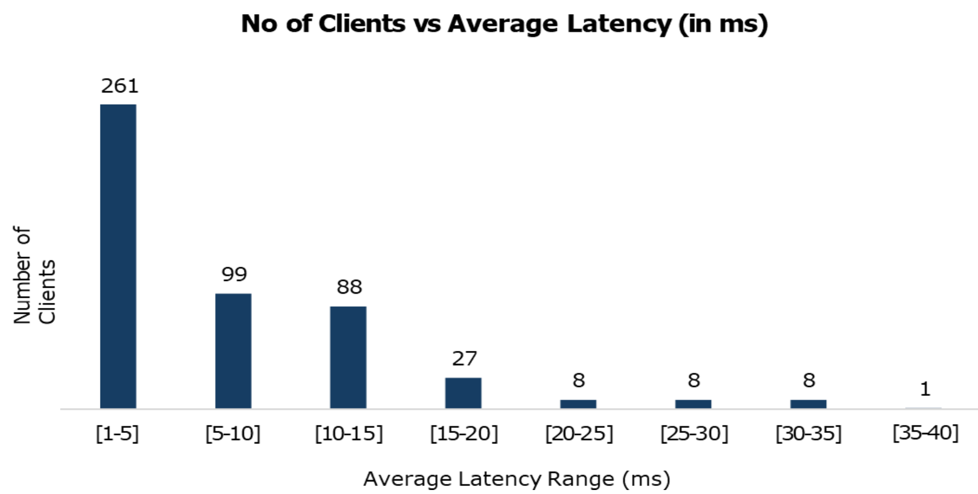
Observations:

- Throughout the 1-hour test duration, there are 0 ping drops.
- The average latency of all 500 clients is less than 40ms.
- Throughput is constant throughout the entire test duration.
- AP did not reboot or crash. No client disconnections were observed for the entire test duration.









Test Procedure:

1. Configure the DUT as per table 1.1.
2. Incrementally associate clients in batches until the target client count (500+) is reached.
3. Apply predefined traffic profiles representing light, medium, and heavy load patterns.
4. Measure aggregate throughput and system stability at each client scale.
5. Monitor for client drops, latency spikes, or system instability.
6. Record performance metrics for each load pattern.

Pass/Fail Criteria:

The test is considered **PASS** if the DUT supports associated clients without instability, client disconnections, or severe performance degradation under all tested load patterns; otherwise, the test is **FAIL**.

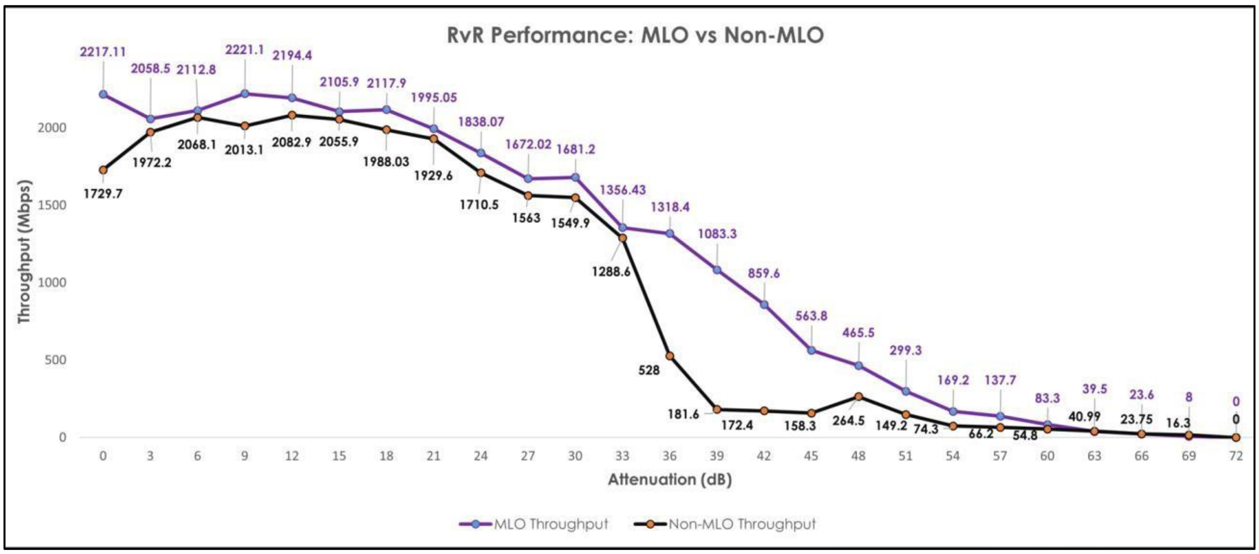
Rate Vs Range – MLO Enabled

Objective:

The objective of the Rate vs Range (RvR) test with Multi-Link Operation (MLO) enabled is to evaluate the DUT's rate adaptation behavior, baseband performance, RF chain efficiency, and multi-link coordination across varying signal levels. By applying controlled attenuation, this test measures how aggregate throughput, per-link and overall MCS selection, PHY rates, spatial stream usage, and link steering behavior degrade as the Wi-Fi client moves farther from the DUT. The test is conducted across multi-frequency bands and channel widths with MLO active to characterize real-world coverage, link robustness, and performance benefits provided by multi-link operation.

Observations:

- MLO consistently outperforms non-MLO across near and medium attenuation levels, achieving ~6% higher peak throughput (~+139 Mbps), confirming a real and repeatable performance gain.
- The most significant improvement is observed at medium attenuation, where MLO maintains 3-4 times higher throughput compared to non-MLO by simultaneously utilizing both 5 GHz and 2.4 GHz links.
- Non-MLO throughput collapses sharply once the 5 GHz link weakens, as the client steers from 5 GHz to 2.4 GHz mid-test, resulting in reduced capacity due to single-band operation.
- MLO sustains higher throughput even when reported RSSI is lower, indicating effective multi-link coordination and traffic distribution across bands, leading to improved stability and extended usable range.



Test Procedure:

1. Configure the DUT as per table 1.1 and enable MLO in the AP.
2. Connect a single MLO capable of STA to the AP to one of the supported frequency bands as mentioned in table 1.1.
3. Set the initial attenuation to 0 dB to represent the strongest signal (closest range).
4. Run the TCP downlink throughput test for 1 minute and measure performance.
5. Increase attenuation in 3 dB increments, and at each step run the same throughput test and record results.
6. Repeat the test until the client disconnects.
7. Record key performance metrics at every attenuation step: RSSI, MCS index, PHY rates, throughput, NSS (number of spatial streams).
8. Identify the knee-drop point (first sharp drop in rate) and the die-off point (where connectivity or throughput collapses).
9. Repeat the test across all supported bands, different traffic types, and directions.

Pass/Fail Criteria:

- The client shall maintain simultaneous MLO links on at least two bands at near and medium attenuation levels. And achieved throughput must be greater than non-MLO scenario.
- Throughput shall be highest at 0 dB of attenuation and decrease gradually as attenuation increases, without abrupt drops before the knee-drop point.
- Bandwidth, MCS, PHY rate, and NSS shall progressively fall back in response to reduced signal strength.
- Connectivity shall be maintained until high attenuation levels, with a clear knee-drop and die-off point observed.

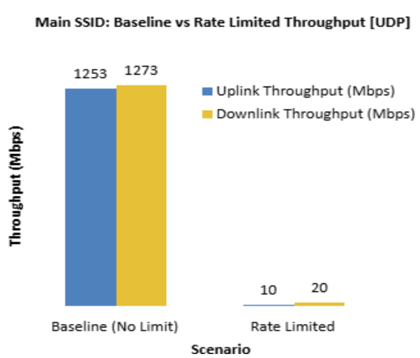
Rate Limiting

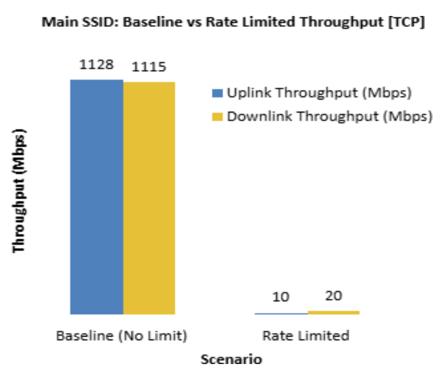
Objective:

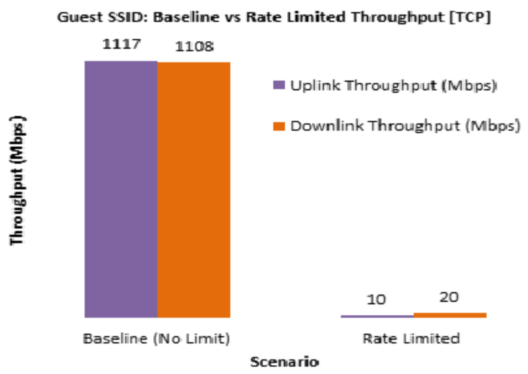
The objective of the Rate Limiting test is to validate that the DUT correctly enforces configured uplink and downlink bandwidth limits on a per-SSID basis. This testing ensures fair bandwidth allocation between Main and Guest networks, confirms that rate limits are applied independently per SSID, and verifies that enabling rate limiting on one SSID does not negatively impact the performance of others.

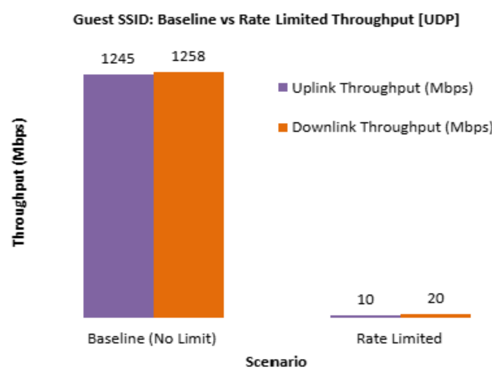
Observations:

- The DUT consistently enforced configured uplink and downlink rate limits on both Main and Guest SSIDs, with stable throughput capped precisely at defined thresholds under TCP and UDP traffic.
- Per-SSID rate limiting operated independently, with no cross-impact between Main and Guest networks, and throughput returned to baseline levels immediately after rate-limit removal.









Pass/Fail Criteria:

Pass if UL and DL throughput on each SSID adheres to configured rate limits independently, remains stable under load, and fully recovers after rate limits are removed; otherwise Fail.

WAN links Test with jitter/latency impairments (WAN performance)

Objective:

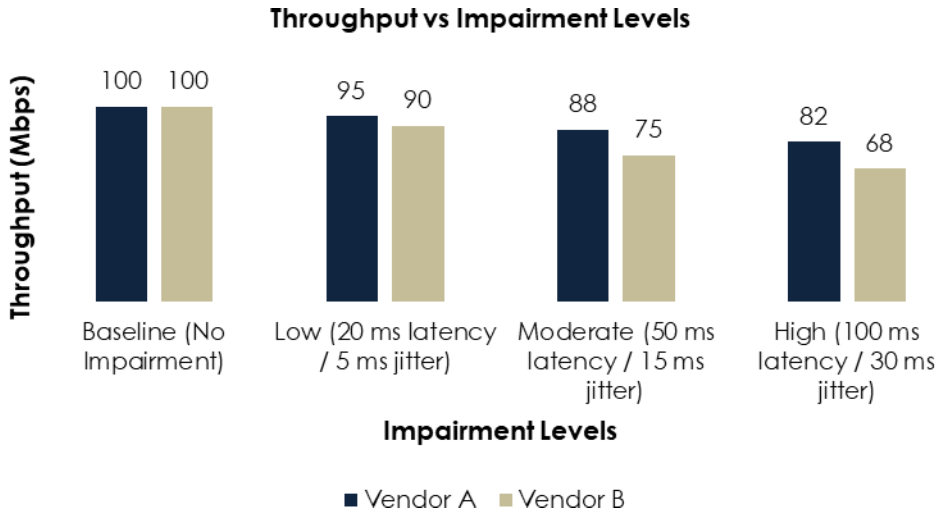
The objective of the WAN Links Test is to evaluate the DUT's performance and stability under WAN conditions with induced jitter and latency impairments. This test validates the DUT's ability to maintain throughput, minimize packet loss, and ensure stable latency despite network degradations typical of real-world WAN environments. The goal is to demonstrate DUT's resilience and effective traffic handling over impaired WAN links.

Test Procedure

1. Configure the DUT with WAN link parameters.
2. Introduce controlled latency and jitter impairments on the WAN link using network emulation tools.
3. Initiate continuous data flows (FTP, HTTP, or UDP streams) through the DUT.
4. Measure throughput, packet loss, latency, and jitter under varying impairment levels.
5. Repeat tests across multiple impairment profiles ranging from low to high jitter and latency.
6. Perform identical tests for Vendor A and Vendor B DUTs under the same WAN conditions.

Observations:

- Vendor A maintained higher and more stable throughput as latency and jitter increased, while Vendor B showed a steeper throughput degradation under moderate and high impairment levels.



Pass / Fail Criteria

- Pass if the DUT maintains throughput within 85% of baseline under impairment.
- Keeps packets below 1% under moderate impairment.
- Demonstrates stable latency and jitter without significant spikes.
- Otherwise, Fail.

MLO Performance Test

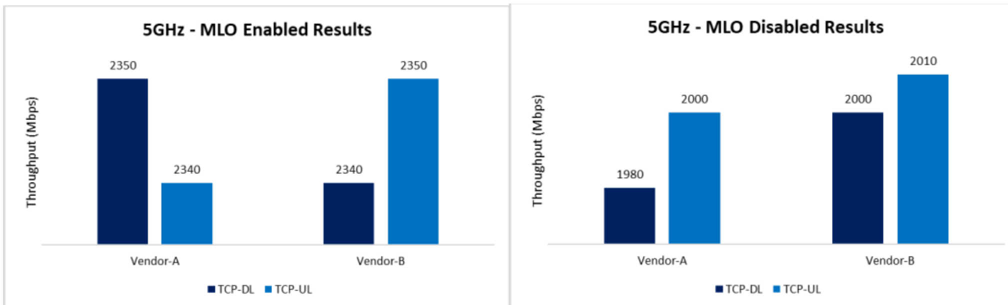
Objective:

The objective of the MLO test cases is to evaluate the performance of the access point (AP) when the Multi-Link Operation (MLO) feature is enabled. These tests aim to assess the AP's performance across multiple frequency bands by measuring parameters such as throughput, interference impact, and simultaneous transmission capacity.

Observations:

- With MLO disabled, both vendors show lower peak throughput, as traffic is constrained to a single 5 GHz link, limiting aggregate capacity and efficiency.
- Enabling MLO results in a clear throughput gain (~15–18%) for both vendors, driven by simultaneous multi-link usage, improved scheduling, and better utilization of available spectrum.

- Vendor-A shows higher TCP-DL gain with MLO enabled, while Vendor-B shows higher TCP-UL gain, indicating differences in uplink/downlink traffic handling and firmware-level MLO optimization.



Test Procedure:

1. Configure the AP as per Table 1.1 and enable MLO on the AP.
2. Identify and verify MLO capabilities of both the AP and STA using Wireshark frame analysis.
3. Connect the MLO-capable STA to the AP with MLO enabled.
4. Run TCP downlink throughput traffic for 2 minutes and record the achieved throughput.
5. Repeat the test for other traffic types (TCP UL, UDP DL, UDP UL).

Pass/Fail Criteria:

PASS if all conditions below are met:

- Throughput Requirement
    a. Achieved throughput (TCP DL/UL) is ≥ 70% of the expected PHY rate, and
    b. Achieved throughput is greater than the non-MLO mode of throughput under the same RF/channel conditions.
- MLO Link Requirement
    c. The STA maintains simultaneous MLO links on at least two bands during the test run (no unintended single-link fallback).
- Protocol/Capability Validation
    d. Wireshark capture confirms MLO capability/support via the correct tagged parameters / information elements and valid MLO negotiation.

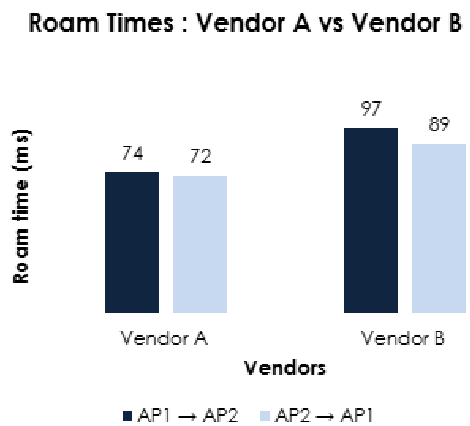
802.11kv Roaming in Mesh setup

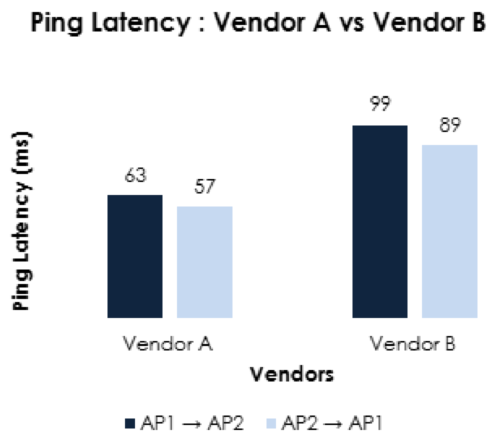
Objective:

The objective of the 802.11k/v Roaming Test is to verify that the DUT provides accurate neighbor reports (11k) and effective BSS transition management (11v) to enable efficient roaming for clients. This test ensures that clients receive proper guidance to roam to a better AP based on signal conditions, resulting in faster, optimized, and seamless roaming performance.

Observations:

- Vendor A demonstrated lower average roam times and reduced ping latency compared to Vendor B during roaming events.
- Both Vendor A and Vendor B remained within acceptable roaming time and latency limits, indicating good roaming performance.





Test Procedure:

1. Configure two mesh APs with 802.11k and 802.11v features enabled.
2. Associate an 802.11k/v–capable client with AP1 and verify stable connectivity.
3. Start continuous ICMP ping traffic from the client to the internet.
4. Initiate roaming from AP1 to AP2 by gradually increasing attenuation between AP1 and the client while simultaneously decreasing attenuation between AP2 and the client.
5. Confirm that the client successfully roams to AP2 without significant packet loss.
6. Reverse the attenuation levels by increasing attenuation between AP2 and the client and decreasing attenuation between AP1 and the client.
7. Verify that the client roams back from AP2 to AP1 while maintaining continuous ping traffic.

Pass / Fail Criteria

- Pass if the client roams successfully between APs using 802.11k/v with acceptable roam times (100ms) and minimal impact to ping latency; otherwise Fail.

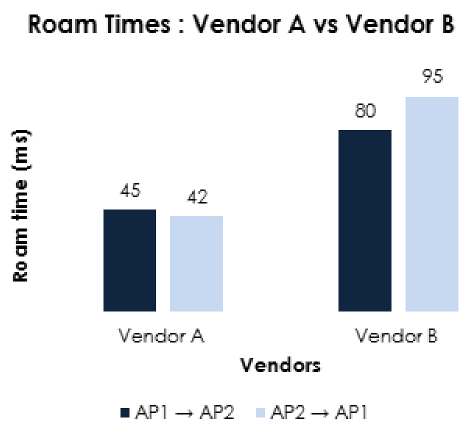
802.11r Roaming in Mesh setup

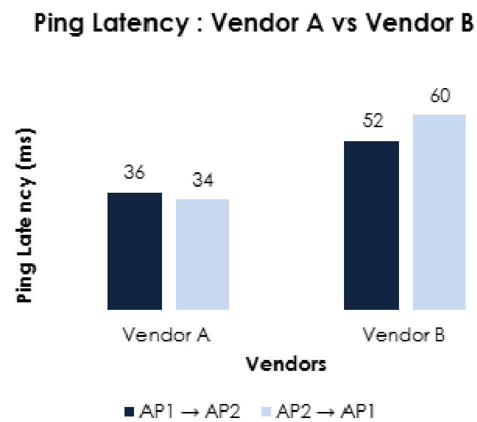
Objective:

The objective of the 802.11r Roaming Test is to verify that the DUT enables fast and seamless roaming using Fast BSS Transition (FT) mechanisms. This test suite covers both FT over-the-air and FT over-the-DS scenarios, ensuring the DUT correctly performs PMK-R0/PMK-R1 derivation, FT authentication exchanges, and reassociation processes. The goal is to confirm reduced roaming latency, minimal packet loss, and consistent key management behavior during transitions between APs.

Observations:

- Vendor A achieved faster roam times, averaging 35–42 ms, while Vendor B required 80–95 ms per handoff.
- Ping latency for Vendor A remained stable at 32–34 ms on average; Vendor B showed higher latency, averaging 40–42 ms.
- Observed 0 packet loss with Vendor A, and 1-2 packet loss with Vendor B during the handoff.





Test Procedure

1. Configure the two Mesh APs as per table 1.1.
2. Associate an 802.11r–capable client with AP1 and verify stable connectivity.
3. Start continuous ICMP ping traffic from the client to the internet.
4. Initiate roaming from AP1 to AP2 by gradually increasing attenuation between AP1 and the client while simultaneously decreasing attenuation between AP2 and the client.
5. Confirm that the client successfully roams to AP2 without significant packet loss.
6. Reverse the attenuation levels by increasing attenuation between AP2 and the client and decreasing attenuation between AP1 and the client.
7. Verify that the client roams back from AP2 to AP1 while maintaining continuous ping traffic.

Pass / Fail Criteria

- Pass if Roam time is less than 50ms with no significant ping loss and latency. Otherwise, fail.

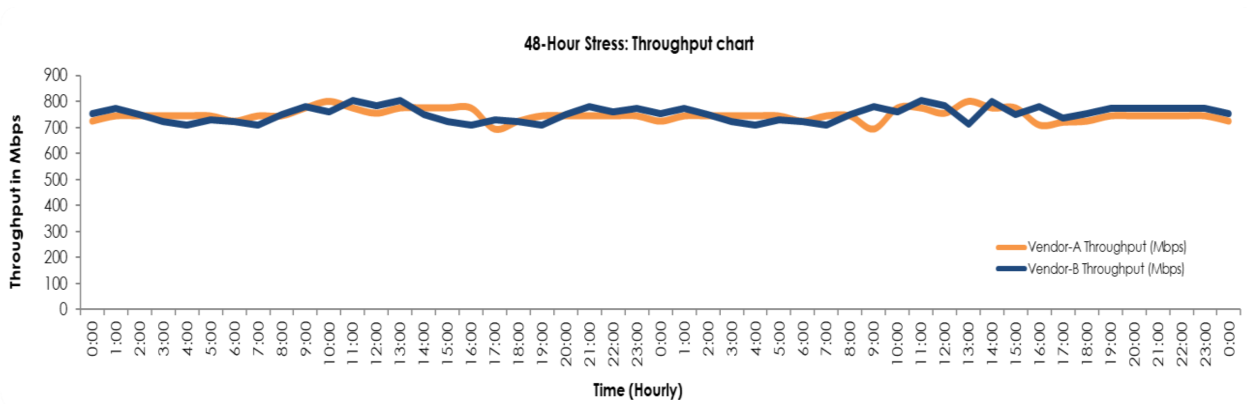
High Stress Test (48 Hours or above)

Objective:

The objective of this test is to validate the stability and reliability of DUT under continuous high stress for 48 hours or above. The test verifies that the system can sustain prolonged traffic load without service interruption, abnormal latency increase, excessive packet loss, client disconnect events, or functional degradation over time.

Observations:

- The AP did not experience any reboots during the entire test.
- Clients also remained connected without any disconnections for the entire test.
- Observed low Latency throughout the test.
- A steady throughput was maintained until the end of the test.
- AP statistics: Memory Utilization – 62%, CPU -19%.



Test Procedure:

1. Configure the DUT as per table 1.1.
2. Connect the maximum number of clients to all bands of DUT.
3. Start Bi-directional TCP and UDP traffic simultaneously on all the clients.
4. Run Ping test and Client reset test parallelly throughout the test duration.
5. Monitor the required parameters of DUT like CPU, Memory, and Thermal.
6. Run Client Visualization to monitor the client's status during the test.

Pass/Fail Criteria:

- The test is considered **PASS** if the DUT sustains continuous traffic throughout the test duration without AP reboots, interruption, or abnormal degradation (high packet loss, persistent latency spikes, or repeated client disconnects); otherwise, the test is **FAIL**.

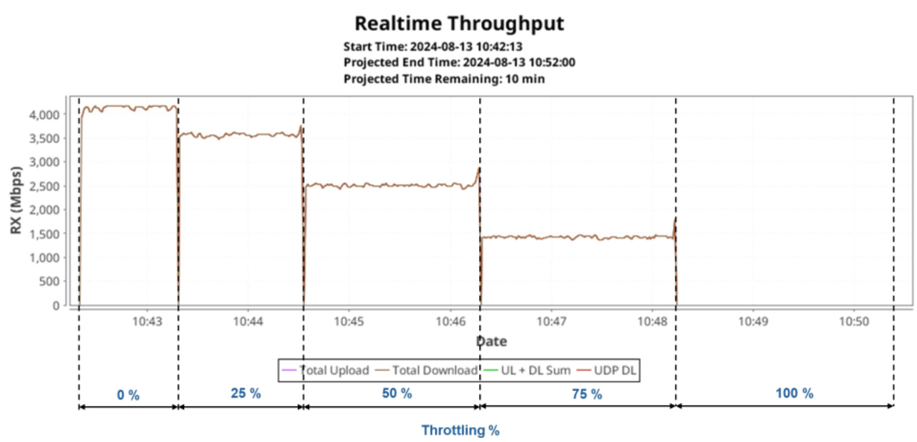
Thermal Throttling

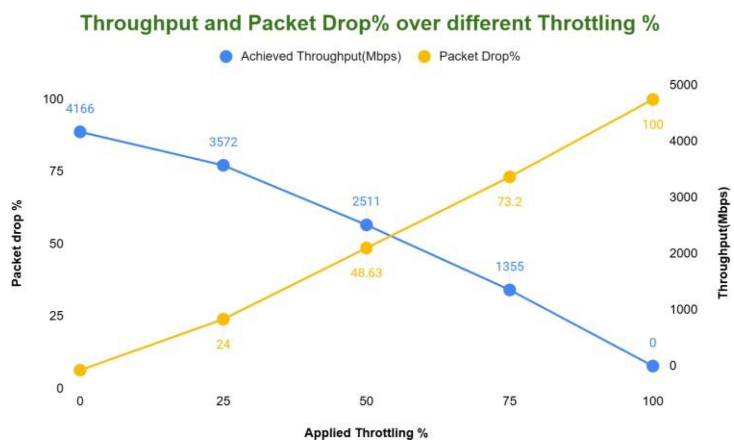
Objective:

The objective of this test is to verify the functionality of the thermal throttling mechanism in Wi-Fi Access Points (APs) by ensuring that the system responds appropriately to high-temperature conditions. The test aims to evaluate the effectiveness of the thermal daemon (thermal) in managing AP temperature.

Observations:

- At 0% throttling, the AP achieved maximum throughput.
- As throttling increased progressively from 0% to 100%, throughput dropped.
- proportionally.
- A clear, direct correlation was observed between throttling percentage and
- achieved throughput.
- The increase in packet drops was intentional, as packets were purposefully dropped to reduce radio activity and airtime.
- At 100% throttling, throughput was effectively zero, i.e., although client is connected, throughput ran is zero which correlates to the thermal daemon functionality when it hits the maximum trip-point.





Test Procedure:

1. Power on the AP and allow it to complete the boot process.
2. Stop the thermal daemon/service on the AP to prevent automatic temperature-based throttling.
3. Identify the cooling devices associated with the Wi-Fi radios (for example: cooling_device0 for 2.4 GHz, cooling_device1 for 5 GHz, etc.).
4. Connect wireless clients to the AP on the target band (2.4 GHz / 5 GHz / 6 GHz), starting with a single client.
5. Verify the current throttling state of the corresponding cooling device.
6. Run a peak throughput traffic test (e.g., TCP Download or TCP Bi-Directional) and record baseline throughput, CPU usage, memory usage, and power consumption.
7. Manually override the cooling device state to apply predefined throttling levels (e.g., 0%, 10%, 30%, 70%, 90%, and 100%), simulating increased thermal constraints.
8. At each throttling level, measure and record the throughput, CPU and memory utilization and power consumption.
9. Restore the throttling state to 0% and verify recovery to normal performance.
10. Repeat the above steps with increased client load to evaluate scalability under throttled conditions.

Pass/Fail Criteria:

- Throughput should decrease proportionally as throttling levels are increased.
- The AP should remain stable and maintain client connectivity at all throttling levels.
- CPU, memory usage, and power consumption should reflect the applied throttling behavior.
- Once throttling is removed, the AP should recover baseline performance without requiring a reboot.

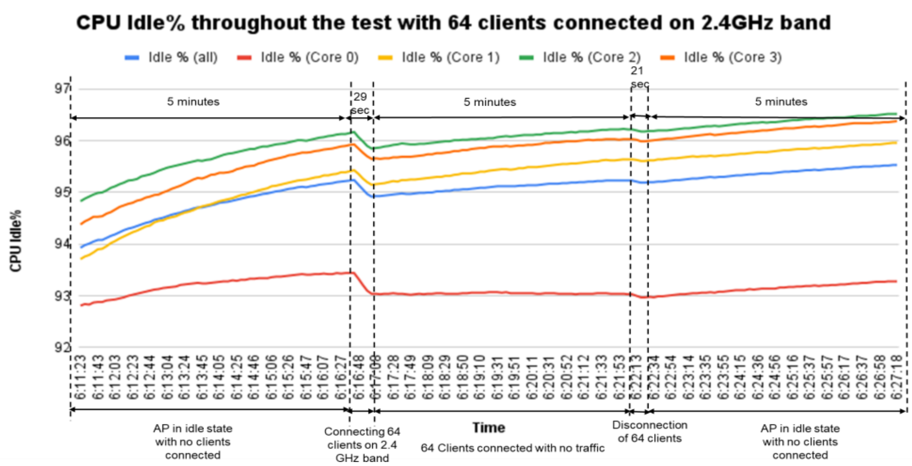
CPU & Memory Profiling

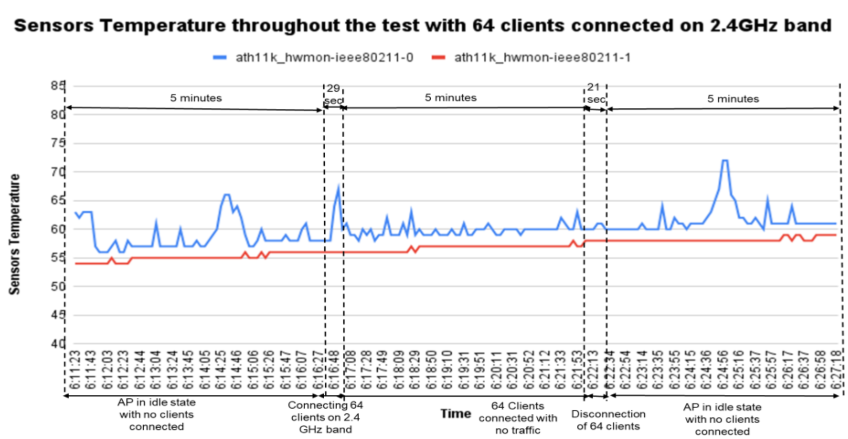
Objective:

The objective of the CPU and Memory Profiling test is to verify that assess how effectively the DUT manages its CPU and memory under different load conditions. This test helps identify usage patterns, potential bottlenecks, memory leaks, and overall system stability while the DUT handles client connections and traffic. The goal is to ensure the DUT operates reliably without excessive CPU or memory usage.

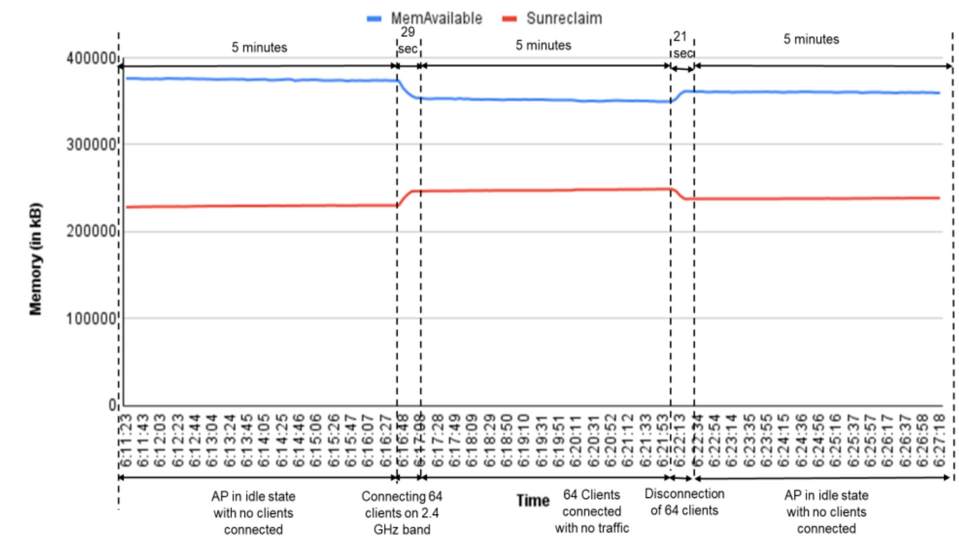
Observations:

- The DUT remained stable under 64-client load with no crashes, reboots, or abnormal behavior, demonstrating robust CPU, memory, and thermal handling.
- Resource utilization (CPU, memory, temperature) showed only expected and transient changes during client association and disconnection, with full recovery afterward, indicating no memory leaks or thermal stress.





Memory throughout the test with 64 clients connected on 2.4GHz band



Test Procedure:

S. No	Test Case	Test Procedure	Expected Results
1	AP idle with 64 clients per band with no active traffic for 1 hour	1. Configure the AP as per Table 1.1 and monitor CPU and memory for 5 minutes. 2. Associate 64 clients per band and keep them connected without traffic for 1 hour. 3. Disconnect all clients after 1 hour and monitor the AP for another 5 minutes. 4. Track CPU and memory usage throughout the test.	1. DUT should remain stable with no crashes or reboots. 2. CPU and memory may rise slightly during client association, remain steady while clients are idle, and return near baseline after disconnection. 3. No memory leaks, abnormal spikes, or client drops should occur.
2	Low load traffic	Connect 64 clients and run low UL/DL traffic (2 Mbps per client) for 1 hour while monitoring CPU and memory.	CPU and memory utilization should remain within 10–15%.
3	Medium load traffic	Connect 64 clients and run moderate UL/DL traffic (10 Mbps per client) for 1 hour while monitoring CPU and memory.	CPU and memory utilization should remain within 30–40%.

4	High load traffic	Connect 64 clients and run high UL/DL traffic (20 Mbps per client) for 1 hour while monitoring CPU and memory.	CPU and memory utilization should remain within 40–50%.

Pass/Fail Criteria:

- The DUT remains operational throughout the test with no crashes, reboots, or service interruptions.
- CPU utilization stays within expected limits with no sustained spikes or core imbalance.
- Memory usage remains stable with no continuous degradation or memory leaks.
- Device temperature stays within safe operating limits with no thermal throttling.
- All connected clients remain associated successfully during the test duration.

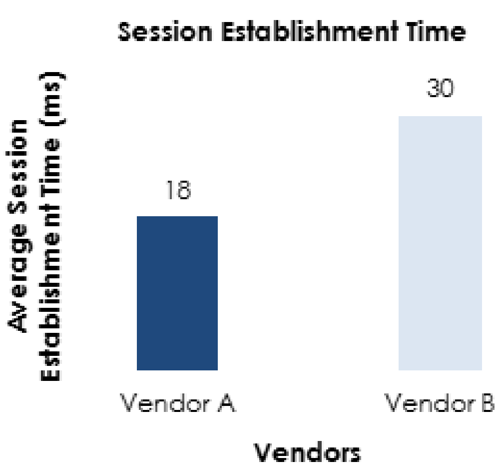
Port Forwarding

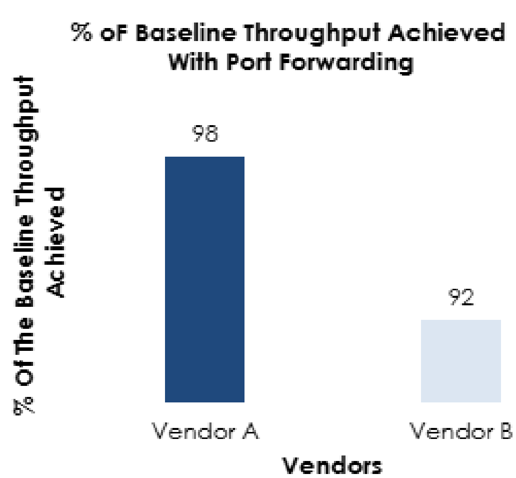
Objective:

The objective of this test is to validate that the DUT correctly supports port forwarding functionality, enabling external clients to reliably access services hosted on the internal network. The test evaluates the DUT's ability to perform accurate traffic redirection, ensure reliable session establishment, and maintain stable latency and throughput for forwarded traffic under comparable conditions.

Observations

- Session establishment time: Vendor A established forwarded sessions faster, averaging 18–20 ms, whereas Vendor B required 28–32 ms.
- Throughput: Vendor A sustained throughput close to baseline (~98%), while Vendor B experienced a drop to 90–92% under forwarded traffic.





Test Procedure:

1. Configure port forwarding rules on the DUT to map external ports to internal server IPs and service ports.
2. Verify baseline connectivity and performance between the external client and internal server.
3. From the external client, initiate TCP/UDP connections to the forwarded ports on the DUT.
4. Measure connection success rate, session establishment time, latency, and throughput for forwarded traffic.

Pass/Fail Criteria:

- The DUT maintains ≥ 95% of baseline throughput for forwarded traffic; otherwise, Fail.
- The session establishment time is ≤ 50 ms; otherwise, Fail.

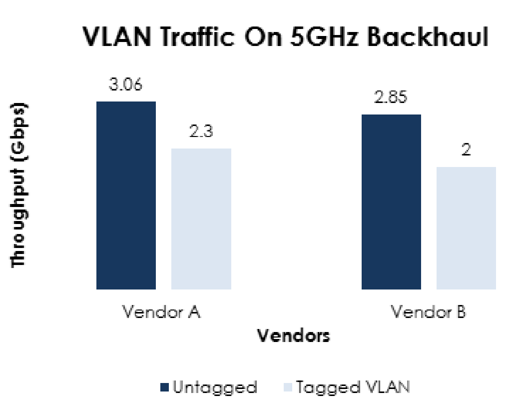
VLAN Mesh Performance

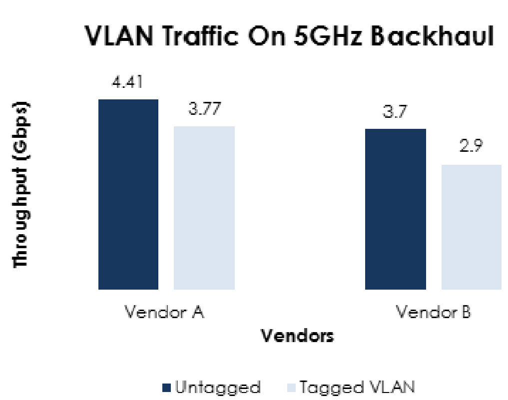
Objective:

The objective of the VLAN Mesh Performance test is to evaluate the DUT's ability to sustain high throughput and stable performance for VLAN-based traffic over a wireless mesh backhaul. This test validates VLAN handling efficiency for baseline (untagged) and tagged VLAN traffic, ensuring predictable throughput behavior and minimal performance degradation across different backhaul bands. The goal is to demonstrate the DUT's robustness and scalability in enterprise-style VLAN deployments over mesh networks.

Observations

- Vendor A consistently delivered higher throughput across all scenarios compared to Vendor B.
- VLAN tagging introduced expected throughput reduction for both vendors; however, Vendor A showed lower degradation.
- Vendor B remained competitive on 5 GHz backhaul but struggled on 6 GHz mesh backhaul.





Test Procedure

1. Configure the DUT in a 1-hop mesh topology with a wired client connected to the leaf node.
2. Establish wireless mesh backhaul using the specified band and channel configuration as per table 1.1.
3. Configure VLAN settings for untagged (baseline) and tagged VLAN traffic.
4. Run TCP traffic from the wired client across the mesh backhaul.
5. Repeat the same procedure for both 5 GHz and 6 GHz backhaul scenarios.

Pass/Fail Criteria:

- Pass if achieved ≥ 75% of baseline (untagged) throughput for tagged VLAN traffic over the mesh backhaul. Otherwise, Fail.

Lab Testing with Real Devices

Basic Suite

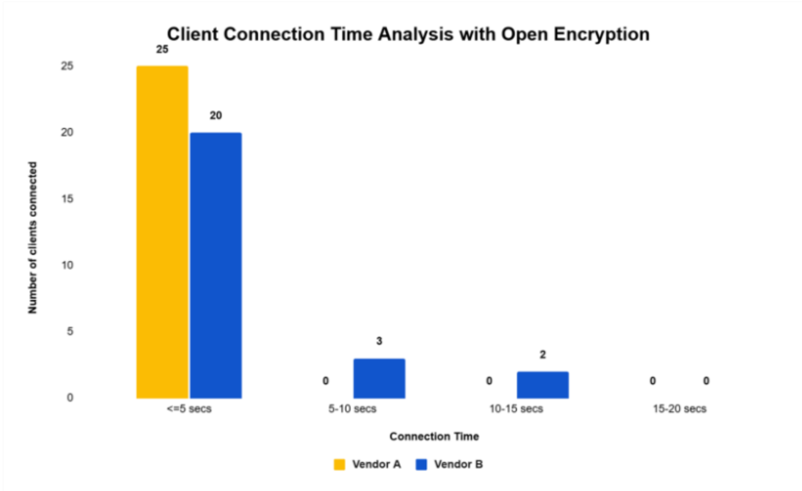
Client Connectivity with Open, WPA2/WPA3 Personal with different OS types

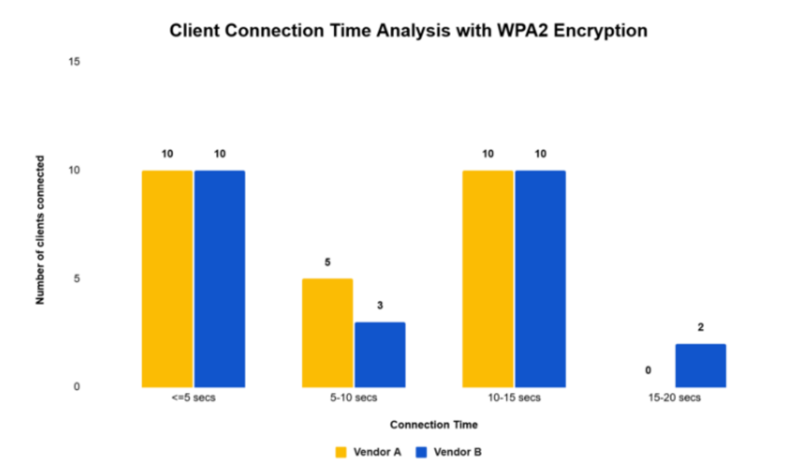
Objective:

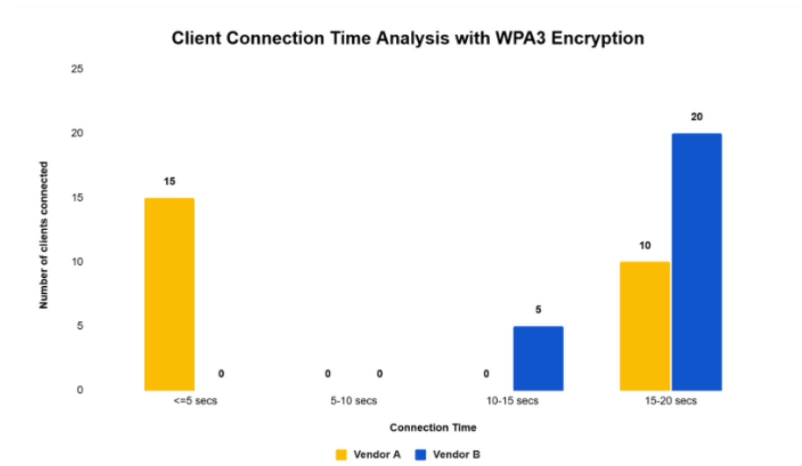
The objective of this test is to evaluate the connectivity of the DUT by connecting the real clients of different OS types like Android, Windows, Linux, MAC, and iOS, with different security types. This involves measuring the time taken for clients to connect, including overall client connectivity time, DHCP time, and the 4-way handshake completion time.

Observations:

- Open: All clients connected within ≤5 sec with Vendor-A, while most clients connected within ≤5 sec with Vendor-B with a few extending to 5–10 sec and 10–15 sec.
- WPA2: Most clients connected within ≤5 sec to 10–15 sec for both Vendor-A and Vendor-B, with Vendor-A showing slightly better consistency and Vendor-B having a few clients connecting in the 15–20 sec range.
- WPA3: Vendor-A had some clients connect within ≤5 sec and most within 15–20 sec, whereas Vendor-B had no clients connect within ≤5 sec, with most clients connecting in the 10–15 sec and 15–20 sec ranges.







Test Procedure:

1. Configure the DUT as per table 1.1.
2. Connect the Android, Linux, Windows, iOS, and MAC devices to the DUT on each supported frequency band.

3. Set up a wireless sniffer to record the connection time.
4. Verify the client's connection status.
5. Calculate the client connection time.
   Connection Time = Time diff (Auth Request to DHCP ACK)
6. Repeat the same steps for other security modes.

Pass/Fail Criteria:

- All clients should successfully connect to the AP using Open, WPA2, and WPA3 security methods.
- Connection time for all the 25 clients connected with Open security mode must be within 5 seconds.
- Connection time for all the 25 clients connected with WPA2-Personal mode must be within 10-15 seconds.
- Connection time for all the 25 clients connected with WPA3-Personal mode must be within 20 seconds.

Ping test with different OS types like Android, Windows, Linux, MAC, iOS

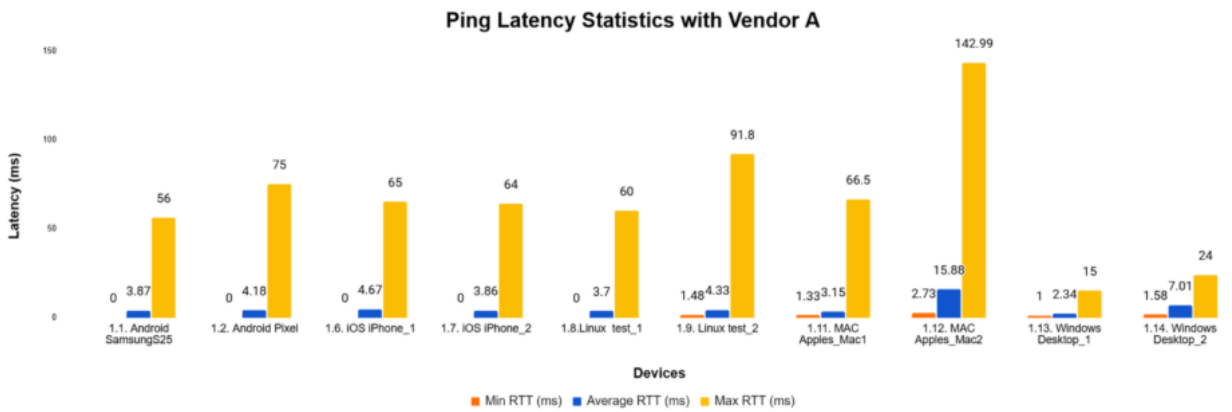
Objective:

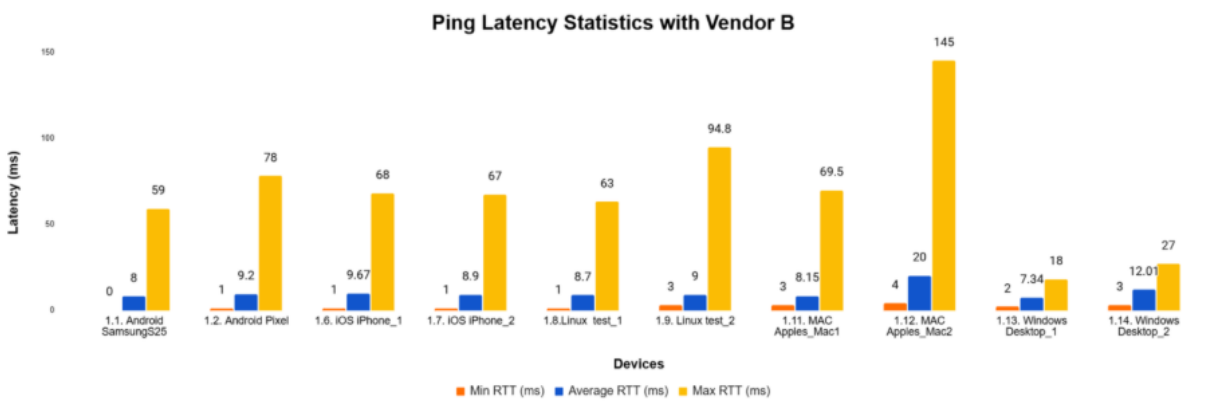
The objective of this test is to verify basic network connectivity, reachability, and stability of the DUT when accessed by clients running different operating systems, including Android, Windows, Linux, macOS, and iOS. This test ensures that ICMP traffic (ping) is handled correctly across all supported OS types, with consistent response time, minimal packet loss, and no OS-specific connectivity issues.

Observations:

- Vendor-A shows lower average RTT (~3–5 ms) across device types including Android, iOS, Linux, macOS, and Windows, compared to Vendor-B which typically shows ~8–12 ms.

- Vendor-B exhibits higher max RTT values (up to ~145 ms) on certain devices such as macOS and Linux, while Vendor-A generally maintains lower max RTT across devices including Windows.





Test Procedure:

1. Configure the DUT as per table 1.1.
2. Associate Android, Linux, Windows, iOS, and MAC devices to the DUT on 2.4GHz band.
3. Ping to the internet/AP Gateway from all the clients for a duration of 15 minutes.
4. Verify the Ping statistics throughout the test.
5. Repeat the same steps with all the supported bands.

Pass/Fail Criteria:

- The ping loss should be < 3%.
- The Average Ping Latency should be <10ms.

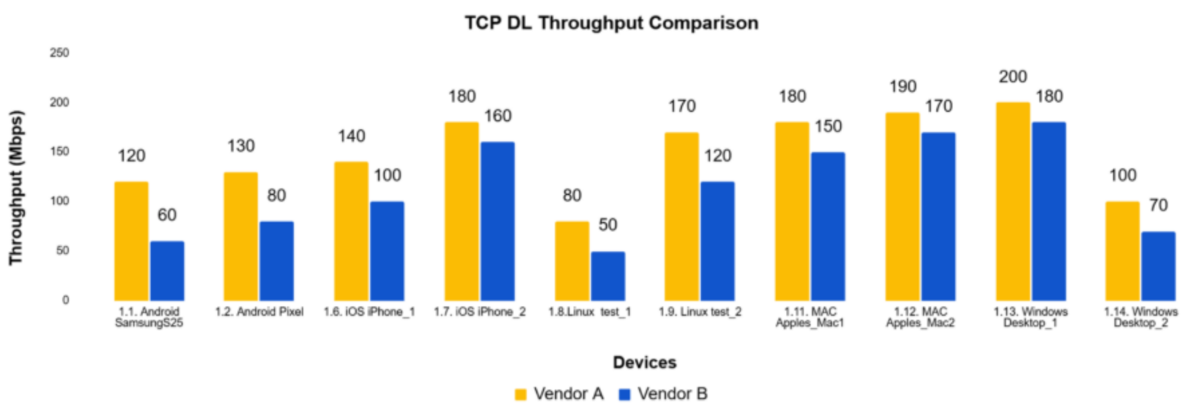
Throughput test with different OS types like Android, Windows, Linux, MAC, and iOS

Objective:

The objective of this test is to connect multiple real clients of different OS types like Android, Windows, Linux, MAC, and iOS to DUT and run traffic with a desired intended load and measure the per client's average throughput. This can be repeated with different traffic types like UDP, TCP in Upload, Download, and Bi directions.

Observations:

- In both TCP upload and download, Vendor-A provides higher average throughput than Vendor-B across all device types.
- The difference is more visible in download, where Vendor-A reaches about 95–190 Mbps, while Vendor-B ranges from 45–170 Mbps.
- Windows and macOS devices achieve the highest throughput for both vendors, with Vendor-A performing better in both directions.



Test Procedure:

1. Configure the DUT as per table 1.1.
2. Connect the devices to the AP to one of the supported frequency bands as mentioned in table 1.1.
3. Run the TCP Downlink throughput test for 2 minutes.
4. Record the results.
5. Repeat the test for different packet sizes, traffic type, and direction.
6. Repeat the test across all supported bands.

Pass/Fail Criteria:

The expected behavior is for the AP to be able to handle several stations (within the limitations of the AP specs) and make sure all Clients get a fair amount of airtime both upstream and downstream. An AP that scales well will not show a significant overall throughput decrease as more Real clients are added.

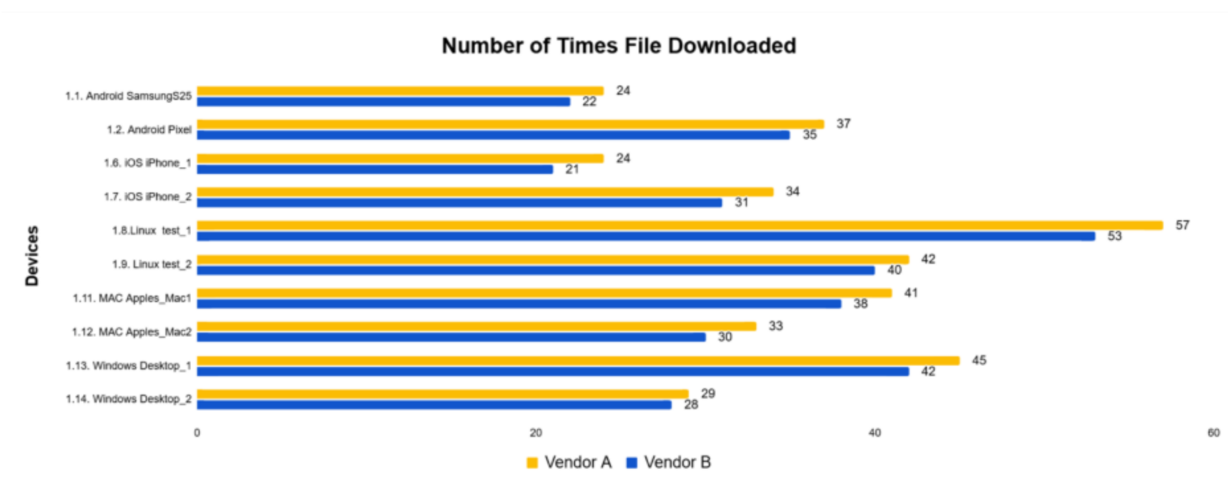
FTP Test

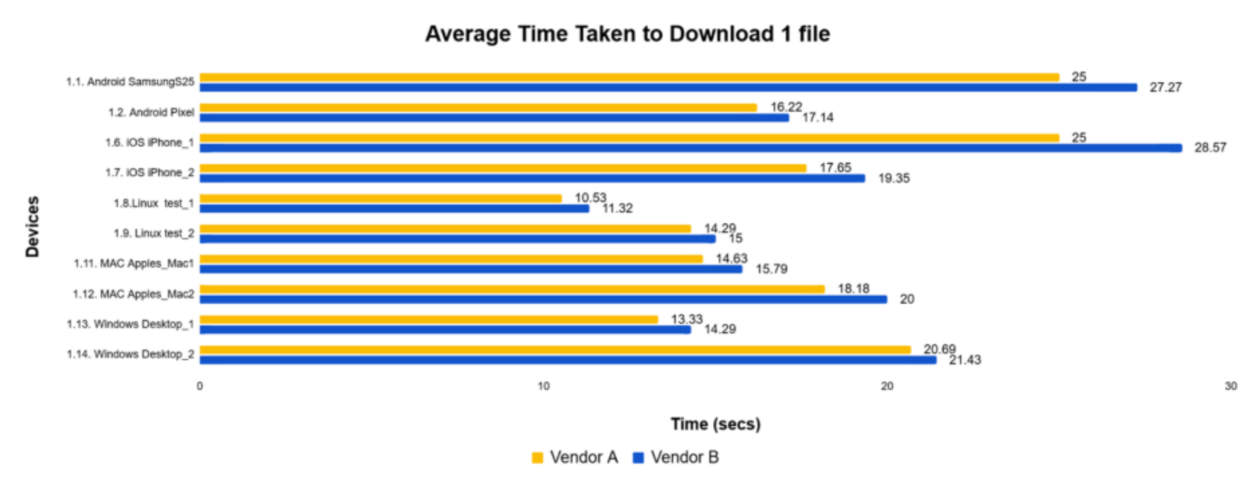
Objective:

The objective of this test is to verify that multiple clients connected to the AP can successfully perform application-layer data transfers using the FTP protocol offline. The test validates reliable file transfer operations using FTP Server.

Observations:

- Vendor A performs better than Vendor B in FTP download tests, with a lower average time per file by ~1–3 seconds across most devices.
- Vendor A records higher FTP download counts, for example Linux test_1 achieves 57 downloads vs 53, and Windows Desktop_1 achieves 45 vs 42 in 10 minutes.
- Linux clients show the best FTP performance on Vendor A, with the lowest average download time of 11–14 seconds and the highest number of downloads.
- Across mobile and desktop devices, Vendor A maintains more consistent and efficient FTP file transfers compared to Vendor B.





Test Procedure:

1. Configure the DUT as per table 1.1.
2. Configure an FTP Server.
3. Connect 25 clients to the DUT in 2.4GHz band.
4. Continuously download the 1GB file from the FTP Server for a test duration of 10 minutes.
5. Record the below data:
    a. No. of Times the file downloaded.
    b. Time taken to Download 1 file.
    c. Minimum, Maximum and Average time taken by the clients to download the file.

Pass/Fail Criteria:

- All the clients should be able to download the file from the FTP Server.
- No FTP session drops and retries should be observed.

HTTP Test

Objective:

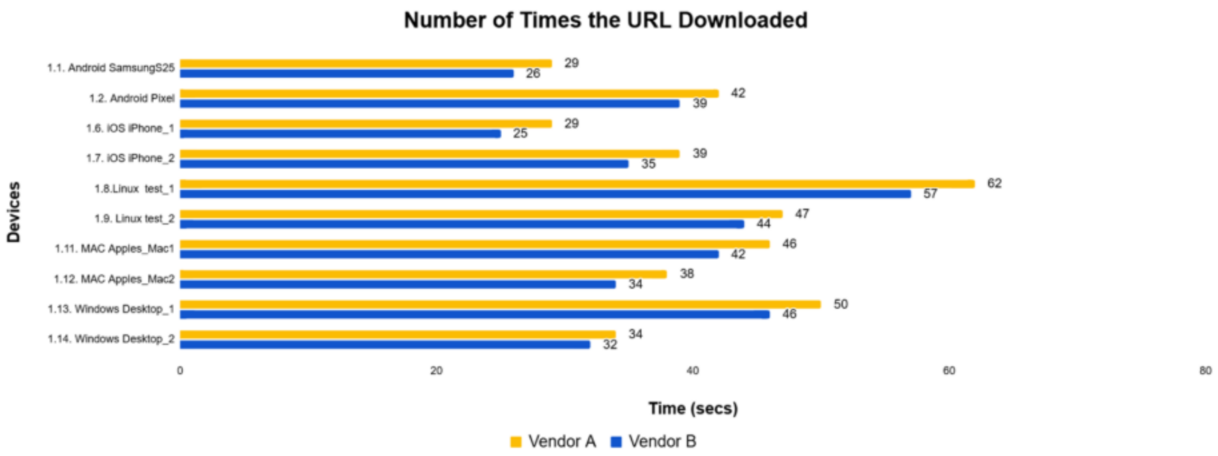
The objective of this test is to verify that multiple clients connected to DUT can successfully perform application-layer data transfers using the HTTP protocol by accessing a specified file in a specific location. The test validates offline file loading using an HTTP server.

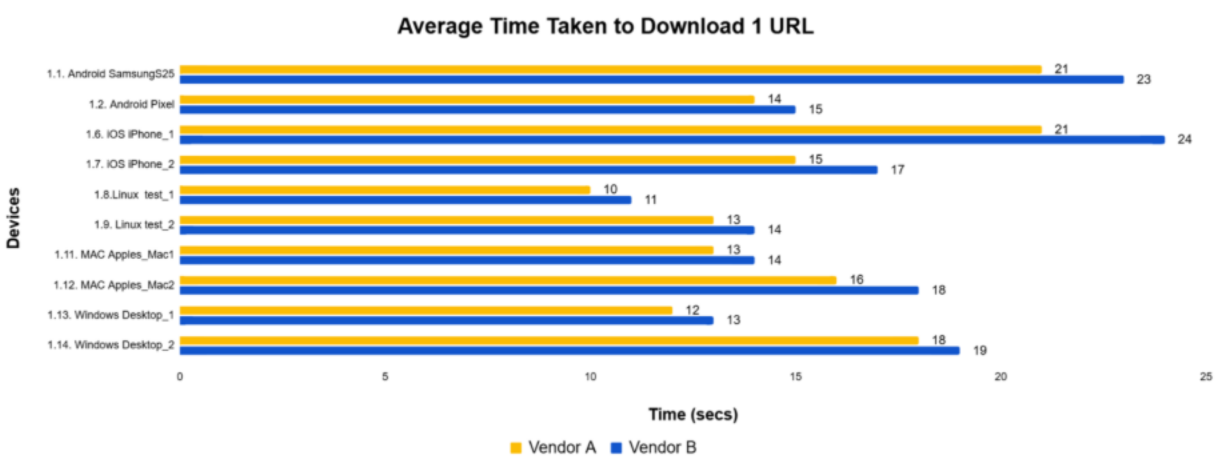
Observations:

- Vendor A shows faster performance than Vendor B across all devices, with average download times lower by 1–3 seconds per file.
- Vendor A achieves higher download counts, for example Linux test_1 completes 62 downloads vs 57 and Windows Desktop_1 completes 50 vs 46 in 10 minutes.
- Vendor A performs best on Linux clients, with the lowest average download time

of 10 seconds and consistently higher throughput compared to Vendor B.

- Across mobile and desktop platforms, Vendor A maintains more consistent and efficient file/webpage downloads than Vendor B.





Test Procedure:

1. Configure the DUT as per Table 1.1.
2. Configure an HTTP server and host a test webpage/file accessible via an HTTPS URL.
3. Connect 25 clients to the DUT on the 2.4 GHz band.

4. Continuously access and download the content from the specified HTTPS webpage for a test duration of 10 minutes.
5. Record the following data:
6. Number of times the webpage/content is successfully loaded or downloaded.
7. Time taken to load/download the webpage once
8. Minimum, Maximum and Average time taken by the clients to load/download the webpage.

Pass/Fail Criteria:

- All the clients should be able to download the file from the HTTP Server.
- No HTTP session drops and retries should be observed.

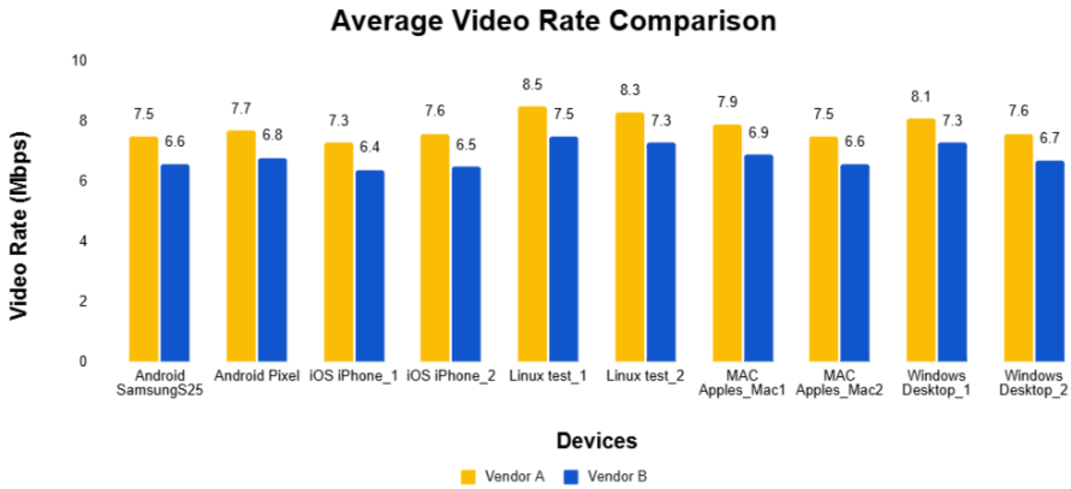
Video Streaming Test

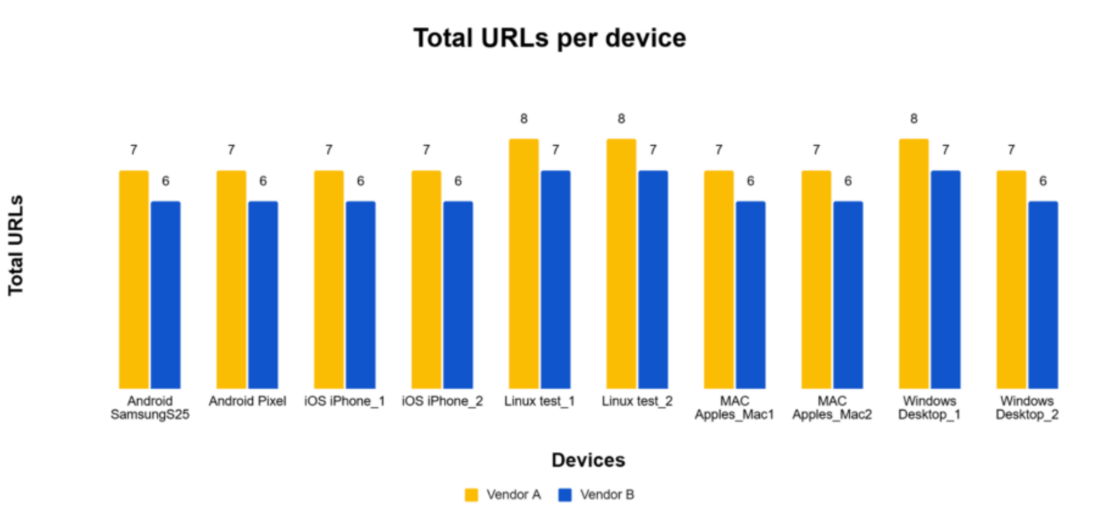
Objective:

To evaluate the Access Point's performance and stability while streaming video using DASH, Progressive Download, and HLS on multiple real client devices, ensuring smooth playback and uninterrupted streaming within the AP's supported capacity limits.

Observations:

- Vendor A delivers higher video rates than Vendor B across all device types, with average video rates of 7.3–8.5 Mbps compared to 6.4–7.5 Mbps for Vendor B.
- Linux and Windows clients show the strongest performance on Vendor A, reaching peak video rates up to 10 Mbps and averaging 8.2–8.5 Mbps.
- Vendor A also completes more video URL plays, with 7–8 URLs per client, while Vendor B consistently completes 6–7 URLs.
- Overall performance consistency is better with Vendor A, reflected in higher minimum video rates (6.0–7.0 Mbps) compared to Vendor B (5.0–6.0 Mbps).





Test Procedure:

1. Configure the DUT (Access Point) as per the test configuration.
2. Set up the video streaming server to support DASH, Progressive Download, and HLS streams.
3. Connect the required number of client devices to the AP on the specified band.
4. Initiate video streaming on all clients using the configured streaming protocol.
5. Run the test for 10 minutes and monitor video playback behavior.
6. Record key metrics such as Min/Max Video Rate, number of buffers, Wait Time, playback interruptions, and errors.

Pass/Fail Criteria:

All connected clients should successfully start and maintain video streaming using DASH, Progressive Download, and HLS with smooth playback, minimal startup delay, no noticeable buffering, and stable client connectivity throughout the test duration.

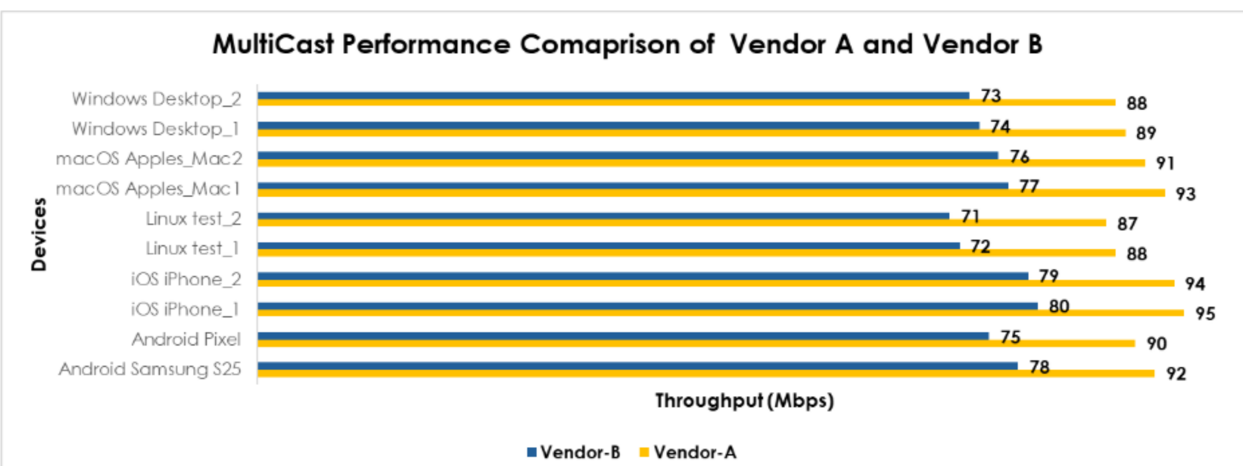
Multicast Test

Objective:

The objective of this test is to validate the multicast traffic performance of the DUT using real client devices across different operating systems, and to verify correct IGMP group membership handling and consistent multicast traffic delivery in terms of throughput and packet integrity.

Observations:

- All real client devices successfully joined the multicast group and received multicast traffic.
- Vendor-A shows more consistent multicast throughput across all device types, indicating stable multicast handling.
- Vendor-B exhibits noticeable variation in multicast throughput between clients, suggesting less uniform multicast delivery.
- No multicast packet loss was observed during the test duration on either vendor, indicating basic multicast reliability.



Test Procedure:

- Configure the DUT as per table 1.1.
- Connect all real devices to the test SSID and verify stable association.
- Initiate multicast UDP traffic from the server to a configured multicast group

address.

- Allow multicast traffic to run for a duration of 10 minutes under steady-state conditions.
- Monitor multicast receptions on all connected clients.
- Record throughput and packet statistics per client.

Pass/Fail Criteria:

All connected clients should successfully receive multicast traffic, and the throughput should be stable without session drops.

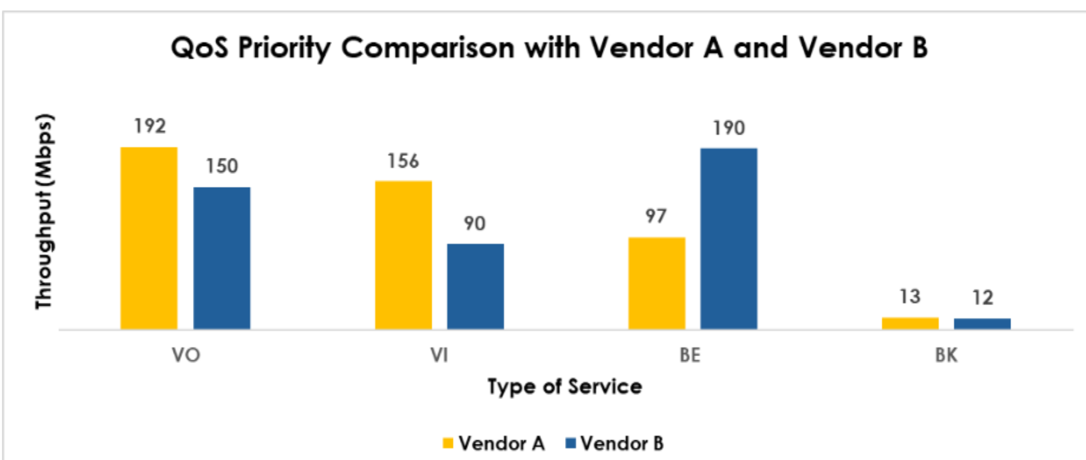
QoS Test

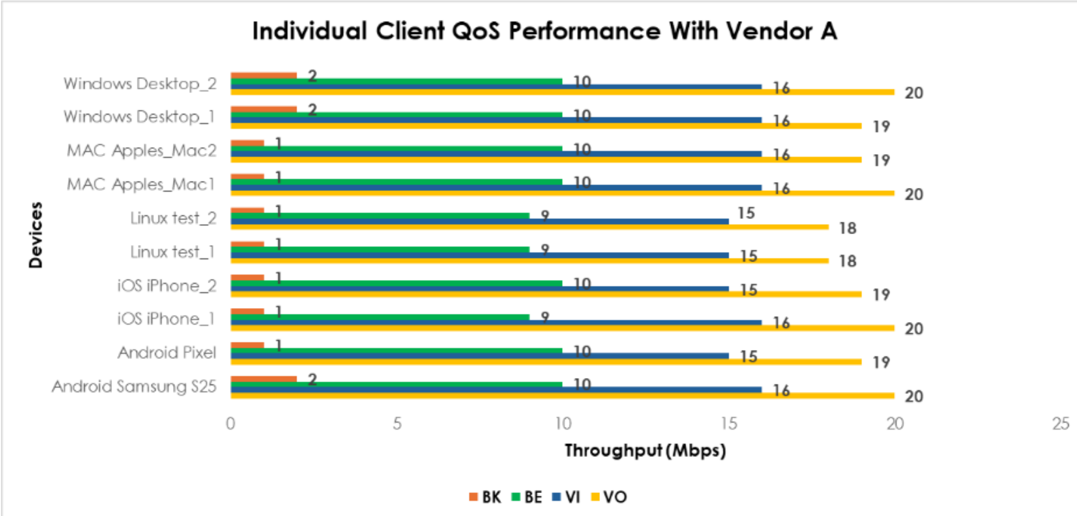
Objective:

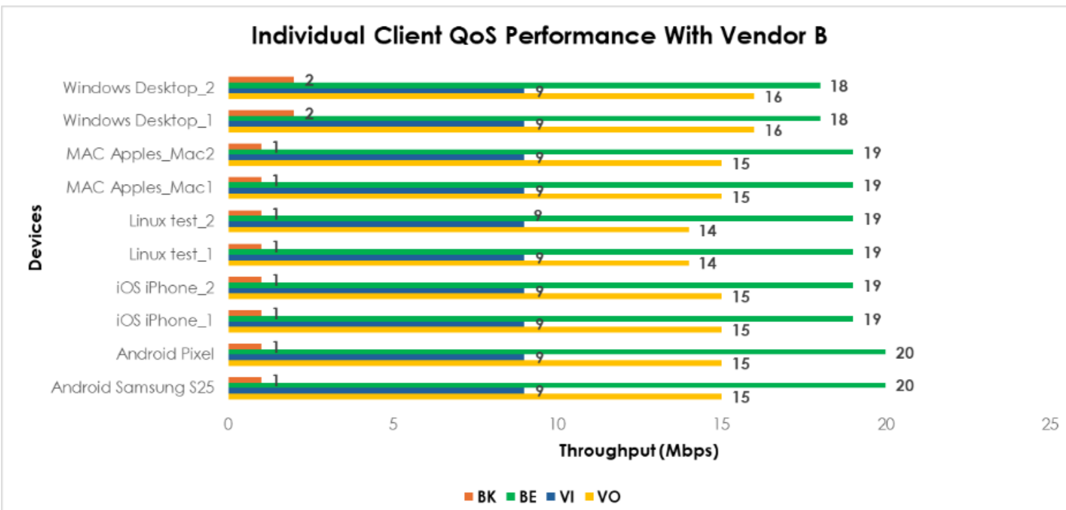
The objective of this Test is to verify that the AP correctly prioritizes network traffic based on QoS classifications, ensuring higher-priority traffic receives preferred handling over lower-priority traffic with Real clients of different OS types.

Observations:

- Vendor-A AP behaves as expected, giving higher priority to Voice (VO) and Video (VI) traffic compared to Best Effort (BE) and Background (BK).
- Vendor-B AP does not clearly prioritize Voice and Video traffic, as Best Effort Traffic achieves higher throughput than VO/VI.







Test Procedure:

1. Configure the DUT as per Table 1.1.
2. Associate the 10 devices of different OS with DUT.
3. Create four traffic streams (VO, VI, BE, BK) and run traffic for all streams concurrently.
4. Observe and record airtime distribution and traffic priority enforcement across the streams.

Pass/Fail Criteria:

The traffic priority order must follow (VO > VI > BE > BK).

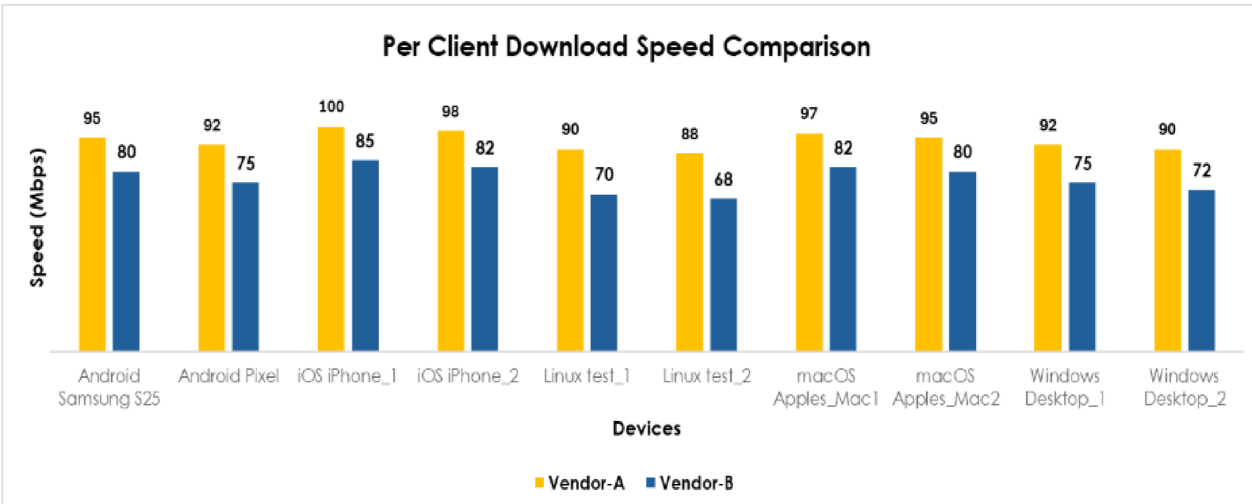
Speed Test

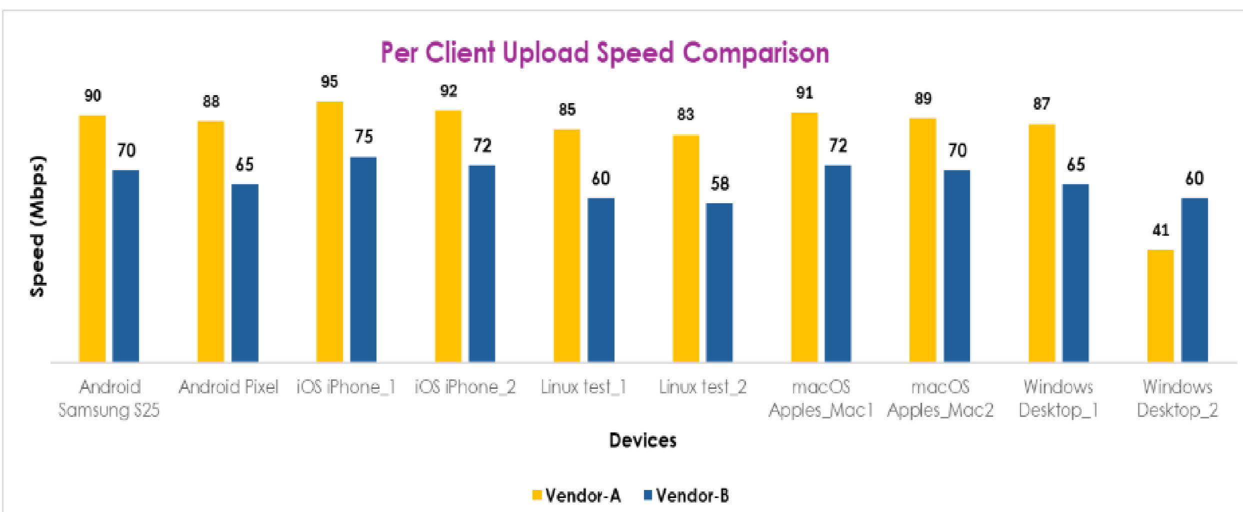
Objective:

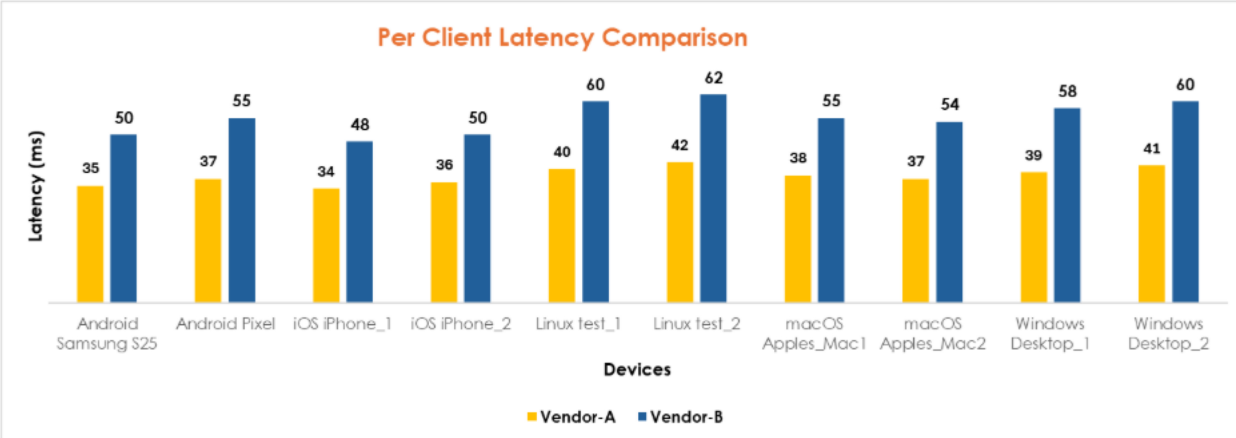
The objective of this test is to evaluate the speed test performance of the DUT using real client devices across different operating systems, and to verify the DUT's ability to provide consistent throughput and latency under normal operating conditions.

Observations:

- Vendor-A delivers higher and more stable speeds across all client devices.
- Vendor-B shows lower speeds compared to Vendor-A.
- Latency is higher on Vendor-B, which impacts overall speed performance.
- Overall, Vendor-A provides better speed test results, while Vendor-B performance is limited by higher latency.







Test Procedure:

1. Configure the DUT as per Table 1.1.
2. Connect all real client devices to the DUT and verify stable associations.
3. Run the speed test application from each client to the test server.
4. Measure and record per-client throughput and latency for each test run.

Pass/Fail Criteria:

- All clients should successfully complete the speed test.
- Stable download and upload speeds should be observed.
- Latency should be within 50 - 100ms.

Advanced Suite

Rate vs Range Test

Objective:

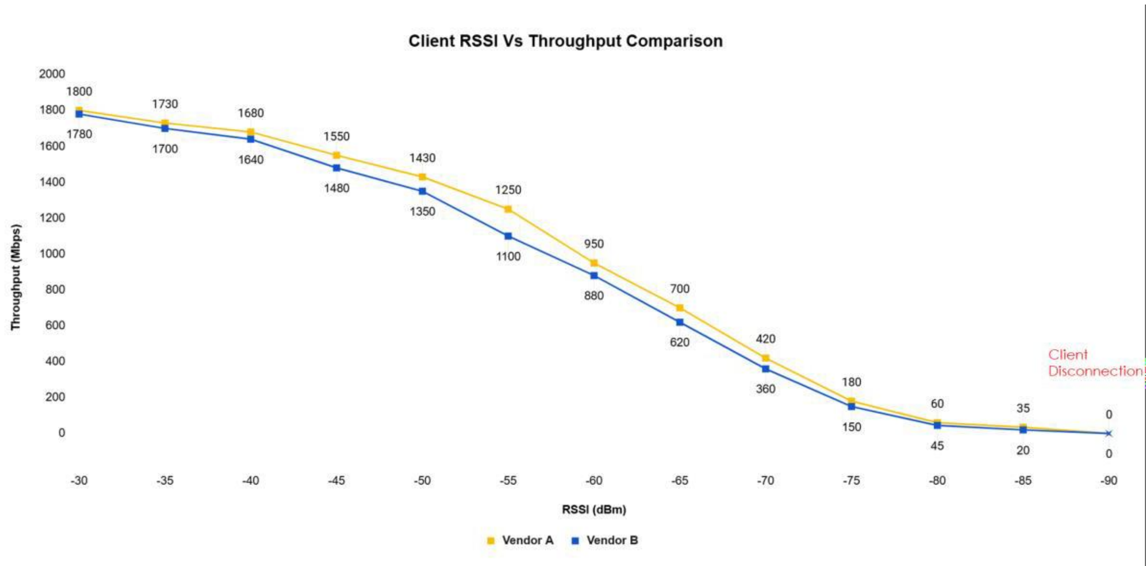
The objective of this test is to evaluate DUT throughput performance over distance using real client devices across different OS types (Windows, Android, iOS, MAC, Linux). Distance is emulated through incremental attenuation, and throughput is measured at each attenuation step. The results are correlated with observed RSSI and signal levels to understand throughput degradation with range and to analyze rate adaptation behavior across different OS platforms.

Observations:

- The Rate vs Range test was performed using a **BE200 2×2 Windows laptop**.
- At strong RSSI levels (-30 to -40 dBm), both vendors achieve high throughput with

stable PHY rates, with Vendor-A showing marginally higher peak throughput than Vendor-B.

- As RSSI decreases from -45 to -60 dBm, throughput degrades gradually on the Windows BE200 client, indicating effective rate adaptation; Vendor-A consistently maintains higher throughput across these mid-range signal conditions.
- At lower RSSI values (-65 to -75 dBm), throughput drops more sharply due to MCS fallback behavior on the Windows client, with Vendor-A sustaining usable throughput over a wider range compared to Vendor-B.
- At very low RSSI (-90 dBm) the client gets disconnected from the DUT.



Test Procedure:

1. Configure the DUT as per table 1.1. and connect the Real client with an RSSI around –35 dBm in 5GHz band.
2. Start the test at the minimum attenuation (strong signal condition).
3. Run UDP/TCP traffic and record throughput, RSSI, and PHY rate.
4. Increase attenuation in fixed steps to simulate increasing distance.
5. At each attenuation level, repeat the throughput test and record throughput, RSSI, PHY rate, and packet loss.
6. Plot the results to generate Rate vs Range curves and analyze rate adaptation behavior.

Pass/Fail Criteria:

The DUT should maintain stable connectivity with smooth throughput degradation, proper MCS rate adaptation, and acceptable packet loss until near sensitivity limits.

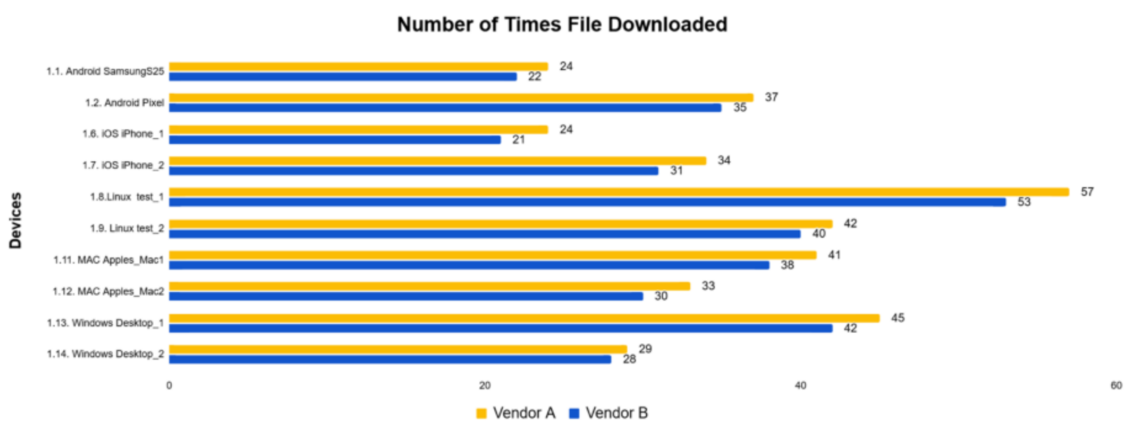
Mixed Traffic Test

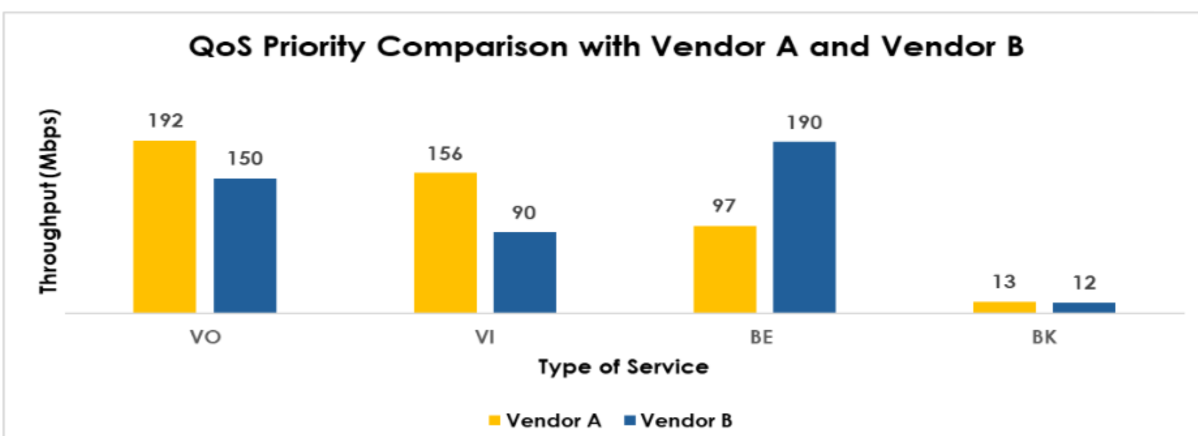
Objective:

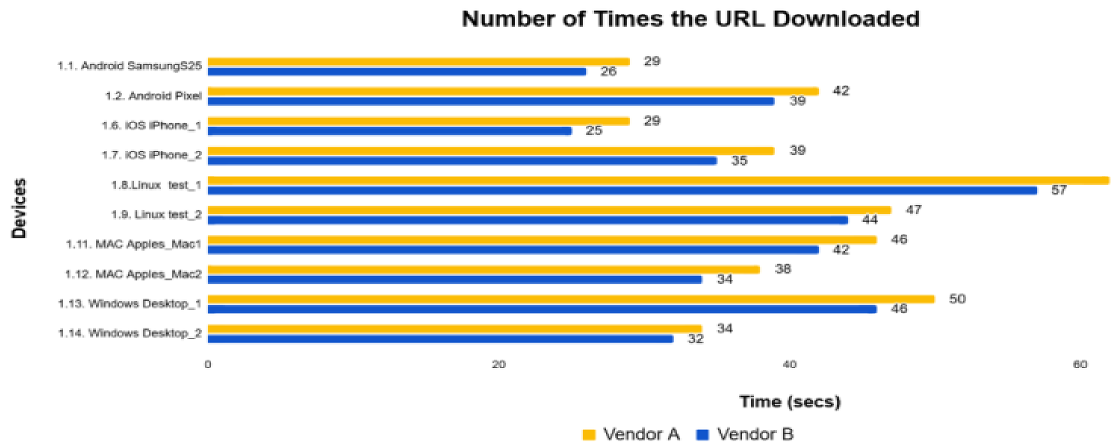
The objective of the Mixed Traffic Test is to evaluate the performance, stability, and Quality of Service (QoS) behavior of the DUT under realistic network conditions by executing Ping, QoS, FTP, HTTP, and Multicast tests either in parallel or in series. This test verifies the DUT's ability to handle multiple traffic types simultaneously or sequentially without impacting connectivity, throughput, latency, or application performance.

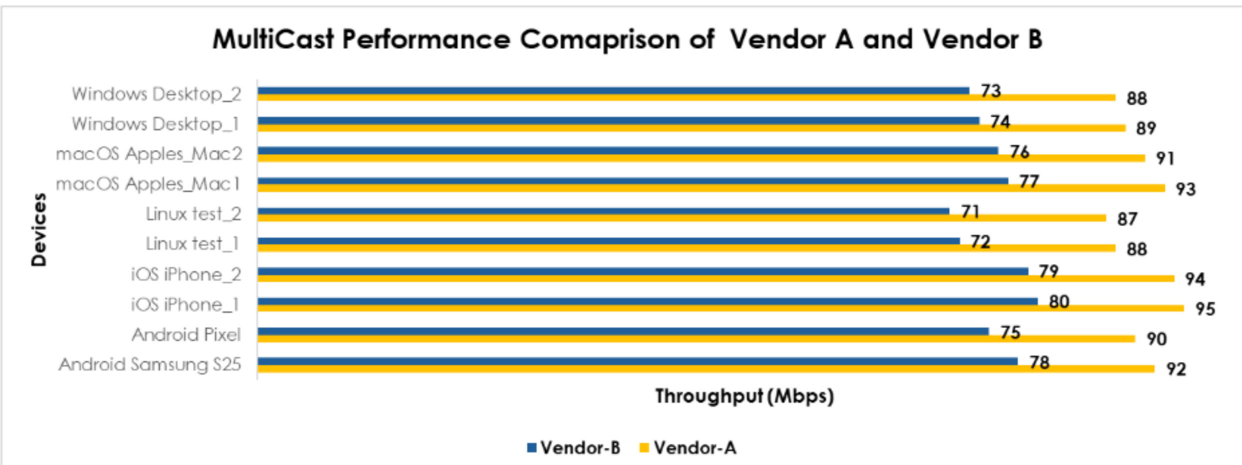
Observations:

- Vendor-A handled simultaneous Ping, QoS, FTP, HTTP, and Multicast traffic more efficiently under mixed traffic conditions.
- Vendor-A achieved a higher number of successful file downloads with more consistent throughput during parallel traffic execution.
- QoS-sensitive traffic on Vendor-A was prioritized effectively, resulting in lower latency and jitter compared to Vendor-B.
- Vendor-B showed relatively higher latency and reduced throughput when all traffic types were executed simultaneously.









Test Procedure:

1. Configure the DUT as per table 1.1.
2. Connect the devices of different OS types to the DUT.
3. Configure traffic profiles for the following test types:
    a. QoS Traffic
    b. FTP Traffic
    c. HTTP Traffic
    d. Multicast Traffic
    e. Ping (ICMP)
4. Execute the configured traffic either in parallel or in series:
    a. Parallel Mode: Ping, QoS, FTP, HTTP, and Multicast tests are executed simultaneously on all connected devices.
    b. Series Mode: Ping, QoS, FTP, HTTP, and Multicast tests are executed sequentially.
5. Run the test for a 10-minute duration.
6. Monitor and record key performance metrics such as latency, jitter, packet loss, throughput, and multicast performance.

Pass/Fail Criteria:

- The AP should be able to handle all configured traffic types simultaneously without failure.
- QoS priority should be in the order of VO>VI>BE>BK.
- Ping packet loss should be <3%, and latency should be <100ms for each device; throughput should remain stable in the multicast test while the FTP and HTTP traffic is running.

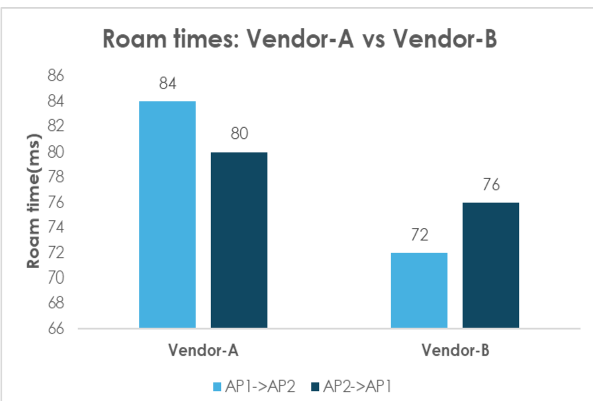
802.11kv Roaming

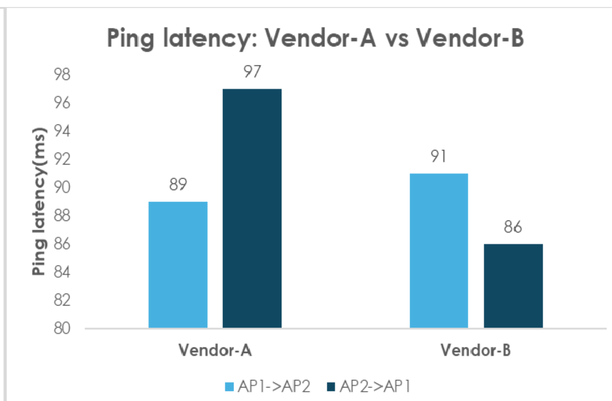
Objective:

The objective of this test is to ensure that the AP correctly sends 802.11k neighbor reports and 802.11v BSS Transition Management (BTM) requests to assist the client during roaming. This test validates that these mechanisms effectively guide the client toward optimal AP selection, resulting in improved roaming efficiency, reduced transition time, and a better overall client roaming experience.

Observations:

- Vendor B demonstrated lower average roam times and reduced ping latency compared to Vendor B during the roaming events.
- Both Vendor A and Vendor B remained within acceptable roaming time and latency limits, indicating good roaming performance.





Test Procedure:

1. Configure two mesh APs with 802.11k and 802.11v features enabled.
2. Connect a real client to the first AP and initiate continuous traffic (e.g., ICMP ping).
3. Trigger the client roaming between the two APs by increasing the attenuation between the client and AP-1 and decreasing the attenuation between the client and AP-2.

4. Measure roam time and ping latency during the roaming event.
5. Repeat the test from AP-2 to AP-1 and for both Vendor A and Vendor B APs under identical conditions.

Pass / Fail Criteria

- Pass if the client roams successfully between APs using 802.11k/v with acceptable roam times (100ms) and minimal impact to ping latency; otherwise Fail.

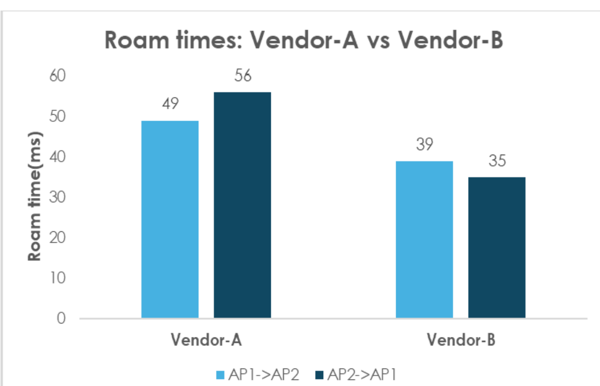
802.11r Roaming

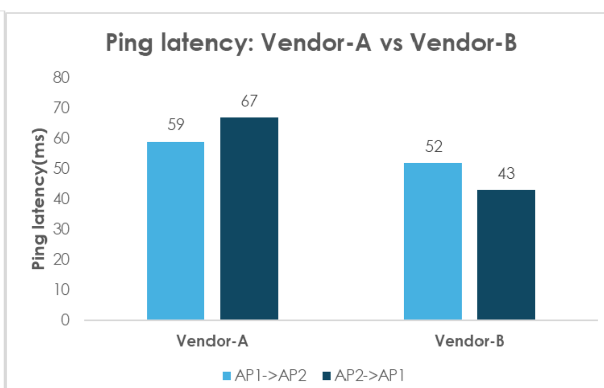
Objective:

The objective of the 802.11r Roaming Test is to verify that the DUT enables fast and seamless roaming using Fast BSS Transition (FT) mechanisms. This test suite covers both FT over-the-air and FT over-the-DS scenarios, ensuring the DUT correctly performs PMK-R0/PMK-R1 derivation, FT authentication exchanges, and reassociation processes. The goal is to confirm reduced roaming latency, minimal packet loss, and consistent key management behavior during transitions between APs.

Observations:

- Vendor B achieved faster roam times, averaging ms, while Vendor A required ms per handoff.
- Ping latency for Vendor B remained stable at ms on average; Vendor B showed higher latency, averaging ms.
- Observed 0% packet loss with Vendor B, and 2-3% packet loss with Vendor A during the handoff.





Test Procedure

1. Configure the two APs as per table 1.1.

2. Associate an 802.11r–capable real client with AP1 and verify stable connectivity.
3. Start continuous ICMP ping traffic from the real client to the internet.
4. Initiate roaming from AP1 to AP2 by gradually increasing attenuation between AP1 and the client while simultaneously decreasing attenuation between AP2 and the client.
5. Confirm that the client successfully roams to AP2 without significant packet loss.
6. Reverse the attenuation levels by increasing attenuation between AP2 and the client and decreasing attenuation between AP1 and the client.
7. Verify that the client roams back from AP2 to AP1 while maintaining continuous ping traffic.
8. Repeat steps 2-7 with Vendor-B AP as well and record the observations.

Pass / Fail Criteria

- Pass if Roam time is less than 50ms with no significant ping loss and latency. Otherwise, fail.

Comprehensive Suite

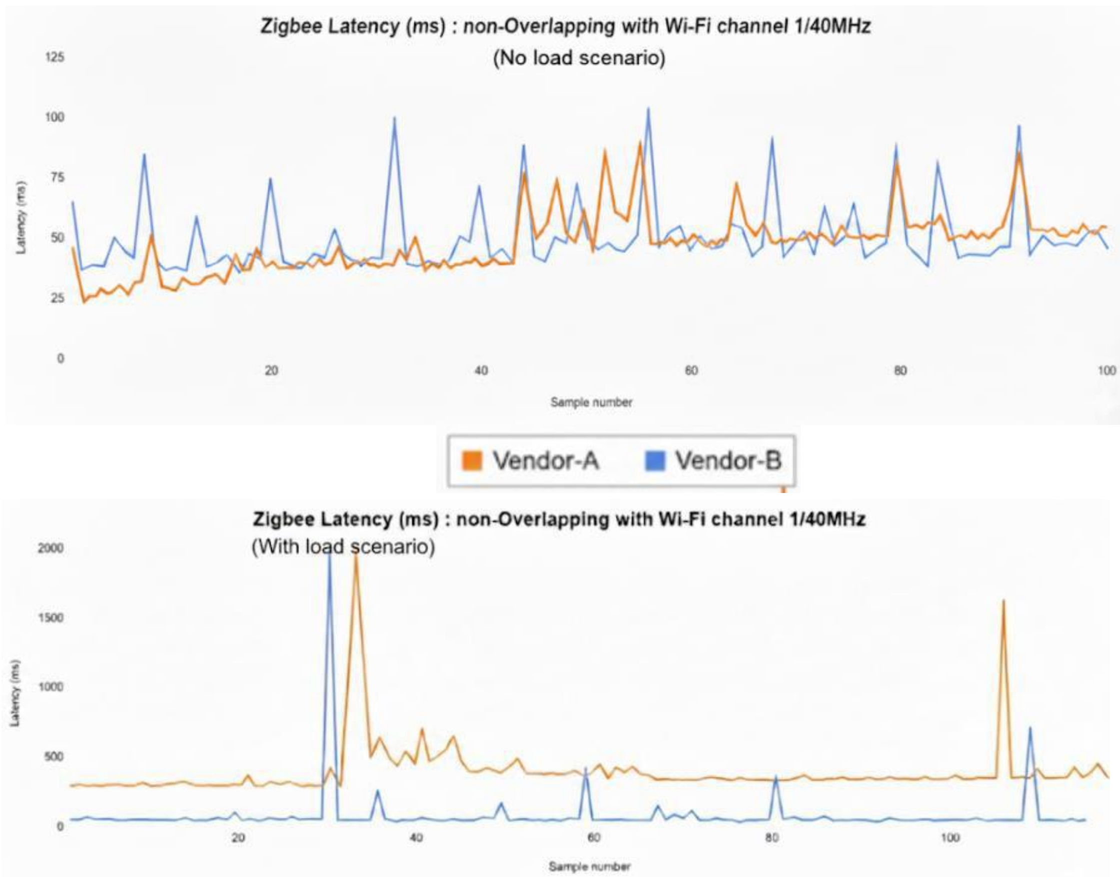
Wi-Fi - Bluetooth/Zigbee Coexistence

Objective:

The objective of the BLE and Wi-Fi coexistence testing is to validate the performance of Wi-Fi and Zigbee coexistence, with particular emphasis on Zigbee client latency as a key parameter. This testing can be performed either in an idle Wi-Fi scenario or under intended Wi-Fi traffic conditions. The goal is to validate how effectively the AP can support both Wi-Fi and Zigbee services simultaneously without experiencing any collisions.

Observations:

- The DUTs successfully connected and operated on 2.4 GHz when there is ZigBee interference added.
- Under 'No load' and 'With load' scenarios where there is varying ZigBee interference, both the DUTs performed well without any timeouts or high latencies.



Test Procedure:

1. Configure the DUT as per table 1.1.
2. Connect a real client to the DUT on the 2.4GHz band in the highest standard supported (802.11ax/be).
3. Run a regular throughput test between the AP and the real client when there is no ZigBee interference in the channel and record the throughput, latency, and the number of timeouts.
4. Introduce different amounts of ZigBee interference (low load, medium load, and high load) and the actual traffic between the station and DUT at the same time.
5. Record the achieved throughput, latency, number of timeouts, and other KPIs.
6. Compare the performance of the AP in all the scenarios.

Pass/Fail Criteria:

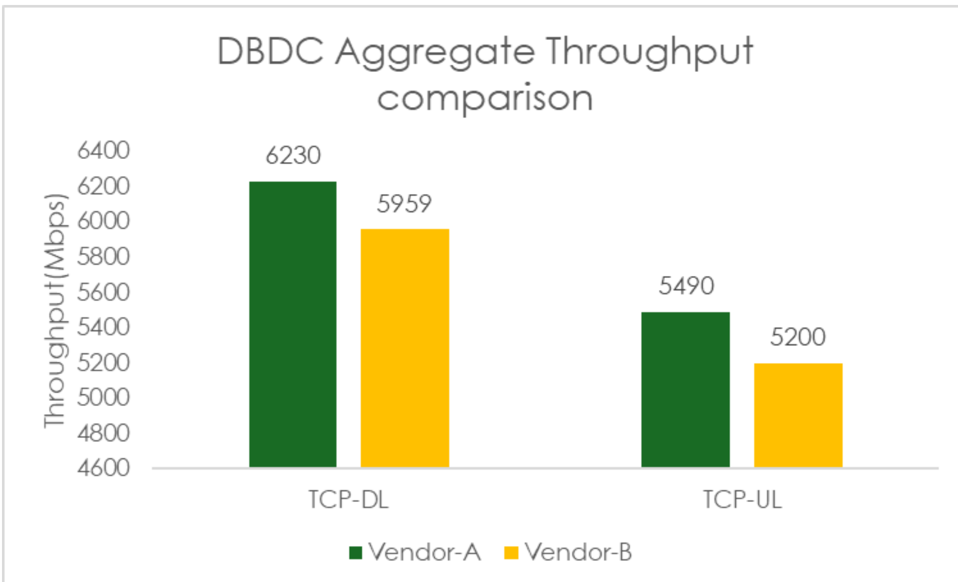
- PASS if the DUT achieves no timeouts and low latencies as usual even when there are different levels of ZigBee interference.
- FAIL if there are many timeouts and high latencies in the presence of ZigBee interference.

Dual Band Dual Concurrency (DBDC) Test

Objective:

The objective of this test is to validate the TCP downlink (DL) and uplink (UL) performance of the Access Point (AP) under dual band, where one client is associated in the 5 GHz band and another client is associated with the 6 GHz band. The test measures the peak aggregate throughput achieved under simultaneous traffic conditions to assess the AP's ability to efficiently handle parallel TCP traffic across multiple bands.

Observations:



Test Procedure:

1. Configure the DUT as per Table 1.1.
2. Connect one STA to the 5G band and another to the 6G band of the DUT.
3. Run TCP DL traffic between the DUT and the STAs in both bands simultaneously.
4. Record the peak throughput obtained on both stations and calculate the aggregated throughput.
5. Repeat steps 3-4 with TCP UL traffic.

Pass/Fail Criteria:

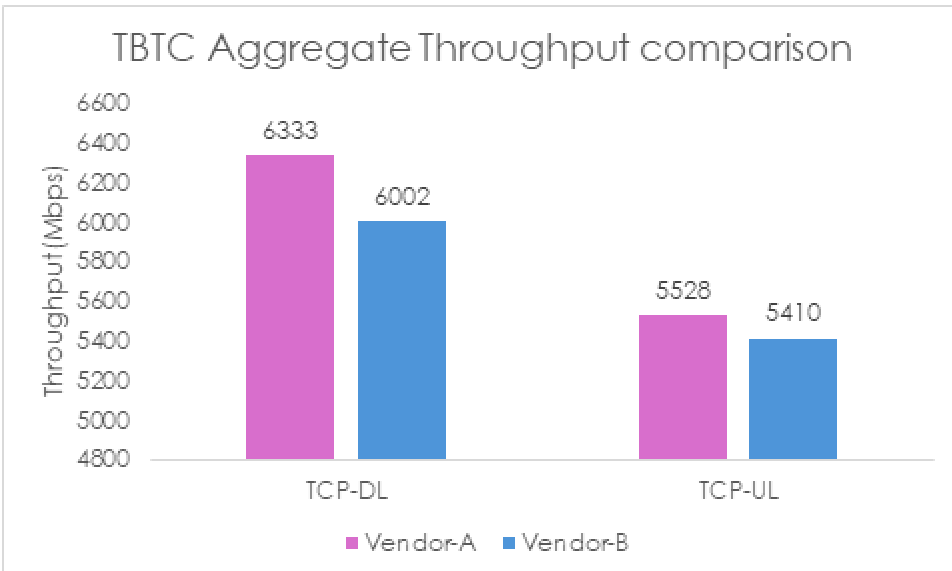
- PASS, if the DUT maintains stable RSSI, delivers peak throughputs on both bands, with 6GHz PHY rates being higher due to the wider bandwidth in both directions.
- FAIL if the PHY rates fluctuate, or the stations get disconnected. Also considered FAIL if the difference between the throughputs obtained in both directions is high.

Tri Band Tri Concurrency (TBTC) Test

Objective:

The objective of this test is to validate the TCP downlink (DL) and uplink (UL) performance of the Access Point (AP) under tri-band, where one client is associated with the 2.4 GHz band, one client is associated with the 5 GHz band, and the other client is associated with 6 GHz. The test measures the peak aggregate throughput achieved under simultaneous traffic conditions to assess the AP's ability to efficiently handle parallel TCP traffic across multiple bands.

Observations:



Test Procedure:

1. Configure the DUT as per Table 1.1.
2. Connect one STA to the 2.4G band, another to the 5G band and another to the 6G band of the DUT.
3. Run TCP DL traffic between the DUT and the STAs in all three bands simultaneously.
4. Record the peak throughput obtained on all the stations and calculate the aggregated throughput.
5. Repeat steps 3-4 with TCP UL traffic.

Pass/Fail Criteria:

- PASS, if the DUT maintains stable RSSI, delivers peak throughputs on all three bands, with 6GHz PHY rates being higher due to the wider bandwidth in both directions.
- FAIL, if the PHY rates fluctuate, or the stations get disconnected. Also considered FAIL if the difference between the throughputs obtained in both directions is high.

High Stress (48 hours and above)

Objective:

The objective of this test is to evaluate the Access Point's stability, scalability, and performance under high-stress conditions with many real client devices (Android, Linux, Windows, and iOS) over an extended duration (≥48 hours). The test increases the number of connected clients and traffic load to assess the AP's ability to sustain high throughput, maintain fair airtime distribution, and preserve client connectivity. The expected behavior is that the AP operates without crashes, reboots, or widespread client drops, while maintaining consistent performance under prolonged heavy load.

Observations:

- The stress test was executed for 48 hours using real Wi-Fi clients to evaluate AP stability and throughput behavior under continuous load.
- Vendor-A: A noticeable drop in throughput was observed during the test when a large portion of clients disconnected and re-associated simultaneously; throughput did not fully return to the earlier steady-state levels afterward.
- Vendor-B: Throughput remained stable across the full duration, with no significant drops or instability events observed during the test window.
- No AP crashes or unexpected resets were observed for either vendor during the 48-hour run.
- Overall, Vendor-B demonstrated stronger stability under sustained medium stress, while Vendor-A showed sensitivity to large-scale client re-association events, impacting throughput consistency.

Test Procedure:

1. Configure the DUT as per table 1.1.
2. Connect a total of 30 – 40 real clients across the DUT's available bands.
3. Apply a high intended load for all the clients connected across all the bands.
4. Monitor client connectivity, system stability, and throughput throughout the test duration.

Pass/Fail Criteria:

- The DUT should maintain stable connectivity and deliver consistent throughput under medium load conditions.
- No client drops, performance degradation, or DUT crashes or reboots should be observed.

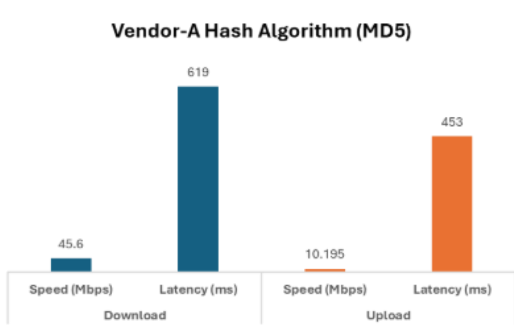
IPSec/GRE Tunneling

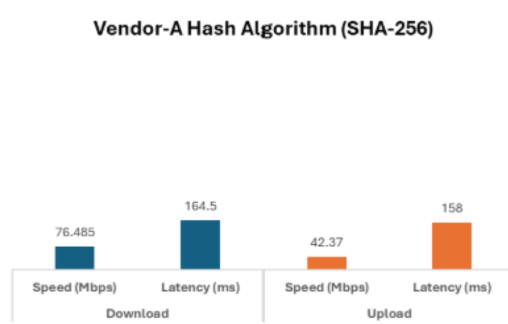
Objective:

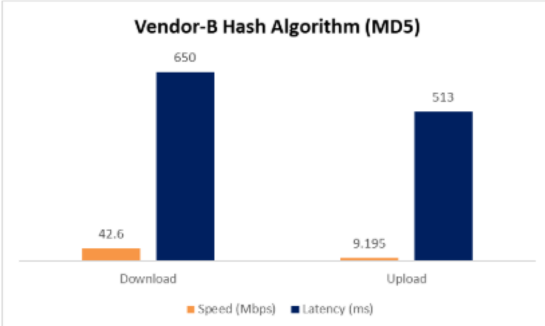
To validate the functionality, stability, and performance impact of IPSec and GRE tunneling on a Wi-Fi Access Point by establishing secure tunnels and verifying client connectivity, application performance, and throughput over public internet access.

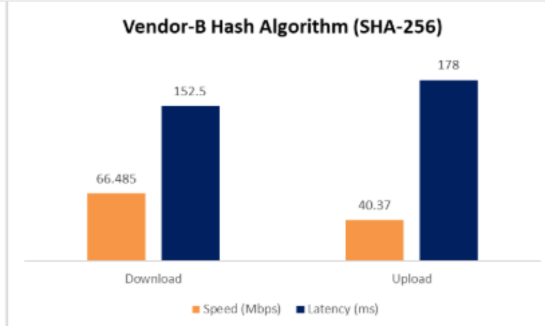
Observations:

- The test was conducted with a single client connected to the 5 GHz public Wi-Fi network using the Ookla Speed Test.
- Both Vendor-A and Vendor-B showed improved overall tunnel performance when configured with SHA-256 compared to MD5, indicating better efficiency with stronger hash algorithms.
- Latency behavior was more stable under SHA-256, resulting in smoother throughput performance during the test run.
- Throughout the IPSec/GRE tunnel validation, no client disconnections or tunnel drops were observed, confirming stable connectivity.
- Overall, the results suggest that SHA-256 is a more suitable hash algorithm for enhanced performance and reliability in tunneled Wi-Fi deployments.









Test Procedure:

1. Configure IPSec/GRE tunneling on the Wi-Fi Access Point and remote gateway/controller.
2. Establish and verify the tunnel is up successfully.
3. Connect a single client to the required SSID.
4. Confirm that the client receives an IP address, and traffic is routed through the tunnel.
5. Run throughput and latency testing using Ookla Speed Test.
6. Record download/upload speed and latency values for analysis.

Pass/Fail Criteria:

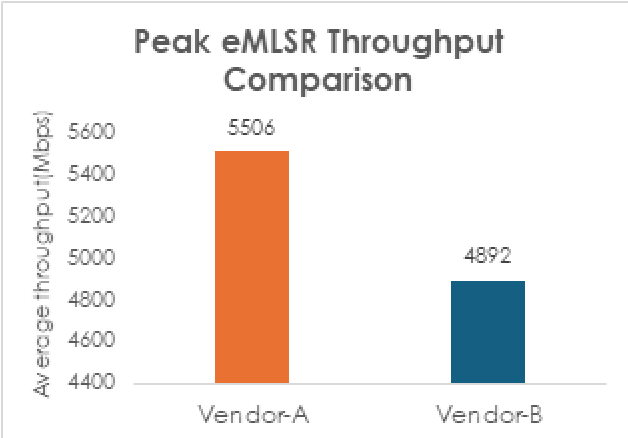
- Tunnel Establishment: Pass if IPSec/GRE tunnel comes up successfully; Fail if tunnel does not establish.
- Client Connectivity: Pass if client stays connected without drops; Fail if frequent disconnects occur.
- Throughput: Pass if non-zero throughput is achieved in both directions; Fail if throughput drops to 0 Mbps.
- Latency: Pass if latency remains within acceptable limit (<1000 ms); Fail if excessive latency or packet loss is observed.
- Stability: Pass if tunnel remains stable during test duration; Fail if tunnel resets or crashes.

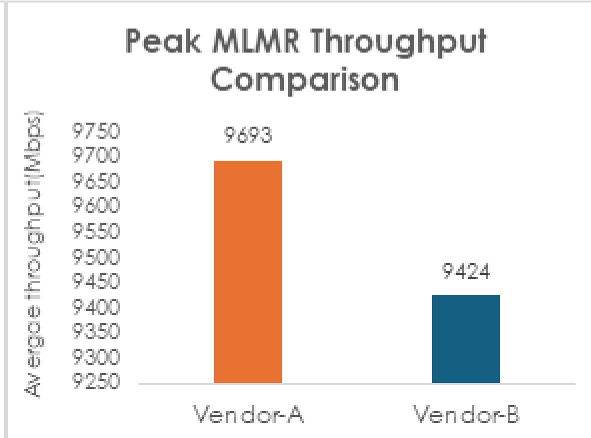
MLO Performance (eMLSR and MLMR clients)

Objective:

The objective of this MLO Performance Test is to verify the performance of the Wi-fi7 AP when MLO feature is enabled and eMLSR or MLMR supported clients are connected to it by verifying the average throughput, number of links etc.

Observations:





Test Procedure:

1. Configure the DUT as per Table 1.1.
2. Associate an eMLSR client with DUT.
3. Run 6 Gbps intended traffic between the client and the upstream port of the AP.
4. Observe and record the average throughput obtained and verify if a link with maximum possible throughput was selected.
5. Repeat the test with MLMR supported client with 10 Gbps intended load and observe the average throughput and aggregated throughput across different links.

Pass/Fail Criteria:

- PASS if the DUT achieves 70% or higher of the PHY rate (for TCP DL and UDP, as applicable).
- FAIL if the achieved throughput is < 70% of the PHY rate.

MLO Client Connectivity under Radar Strike

Objective:

The objective of this MLO Connectivity under Radar Strike Test is to verify the behavior of the Wi-fi7 AP and different real clients when the AP experiences a radar strike in the current channel when there is an MLO supported client connected. This helps the vendor to understand if the AP and the clients honor the DFS regulations in case of radar.

Observations:

Test-Case	Wi-Fi STA	Region	Connected to (Before Channel switch request)	Connected to (During CAC)	Connected to (After CAC)	Ping Loss (Before CSA initiated)	Ping Loss (Upon CSA issued and	Ping Loss (After CAC)

							CAC started)	
check ML interface when channel switch to **36/320MHz**	Station-A	EU	6G	6G	6G	0	2	0
check ML interface when channel switch to **36/320MHz**	Station-B	EU	5G	2G	2G	0	0	0
check ML interface when channel switch to **128/320MHz**	Station-A	EU	6G	6G	6G	0	2	0
check ML interface when channel switch to **128/320MHz**	Station-B	EU	5G	2G	2G	0	0	0

Test Procedure:

1. Configure the DUT as per Table 1.1.
2. Connect the real client to the DUT when the AP is configured to a non-DFS channel.
3. Change the channel of the DUT to a DFS channel manually.
4. Observe the client connectivity before, during and after the channel switch (CAC) and record the ping loss.
5. Repeat the test with the initial channel being a DFS channel and record the same observations.

Pass/Fail Criteria:

- PASS if the DUT switches to a non-DFS channel, and the ML interface changes to another link during the CAC with minimal ping loss.
- FAIL if the ML interface sticks to the same link and the ping loss is high.

Test House Testing with Real Clients

Basic Test Suite

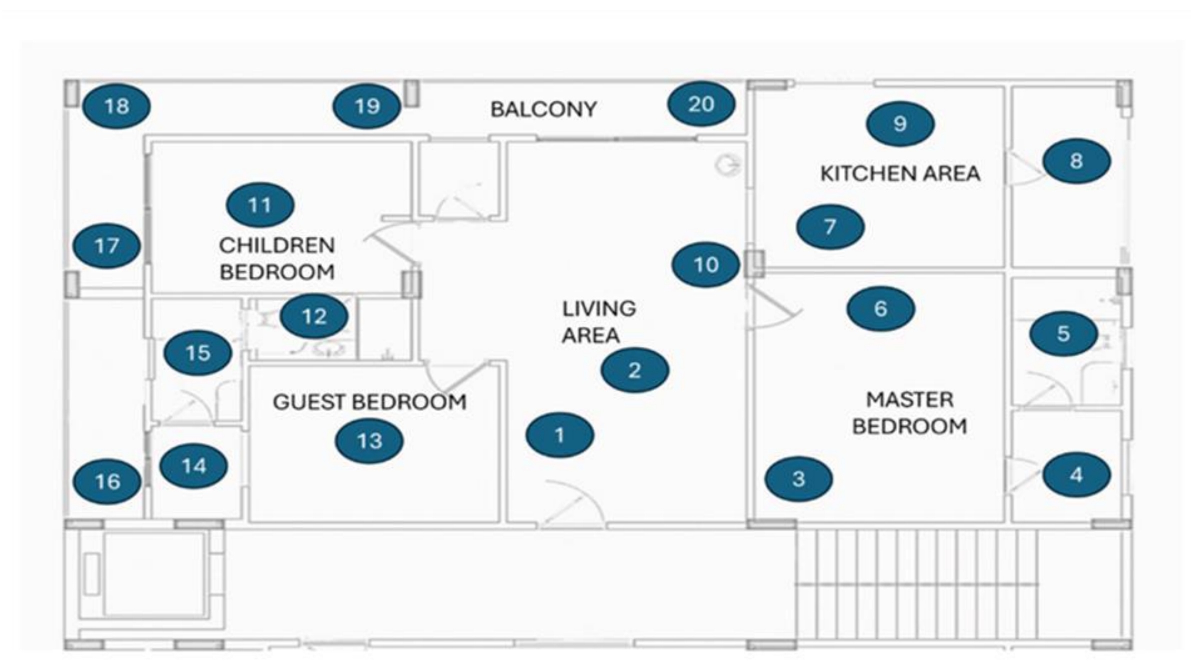
Coverage Test

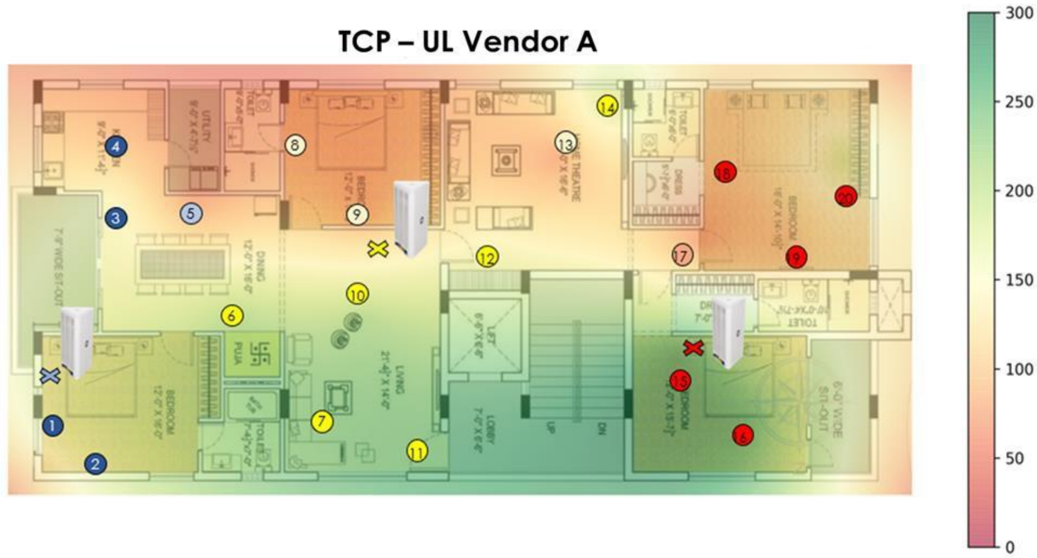
Objective

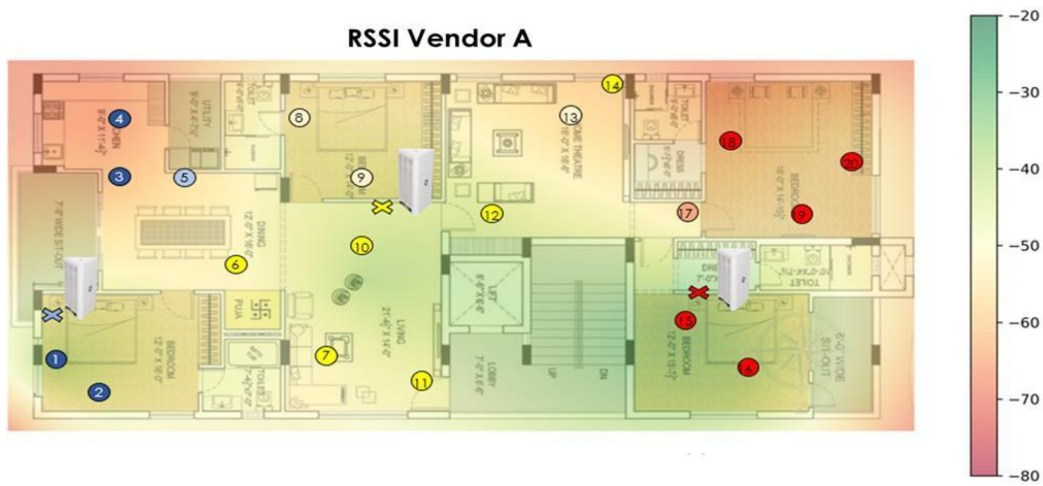
To evaluate Wi-Fi coverage and TCP throughput performance across a 2,500 sq. ft. area by measuring RSSI and uplink/downlink throughput at multiple locations, and to verify the absence of coverage dead zones.

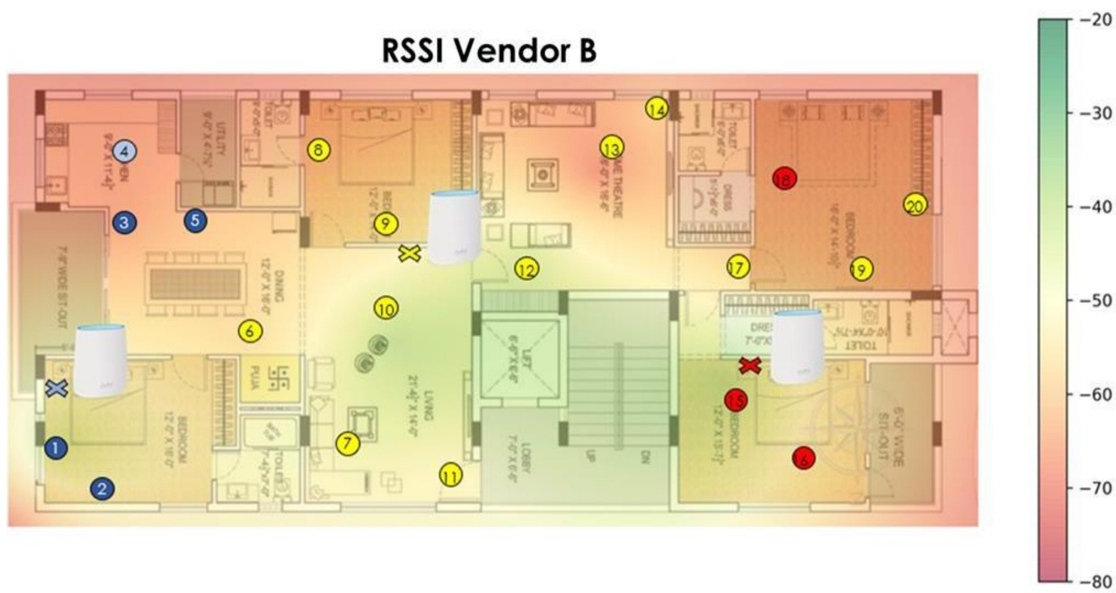
Observations

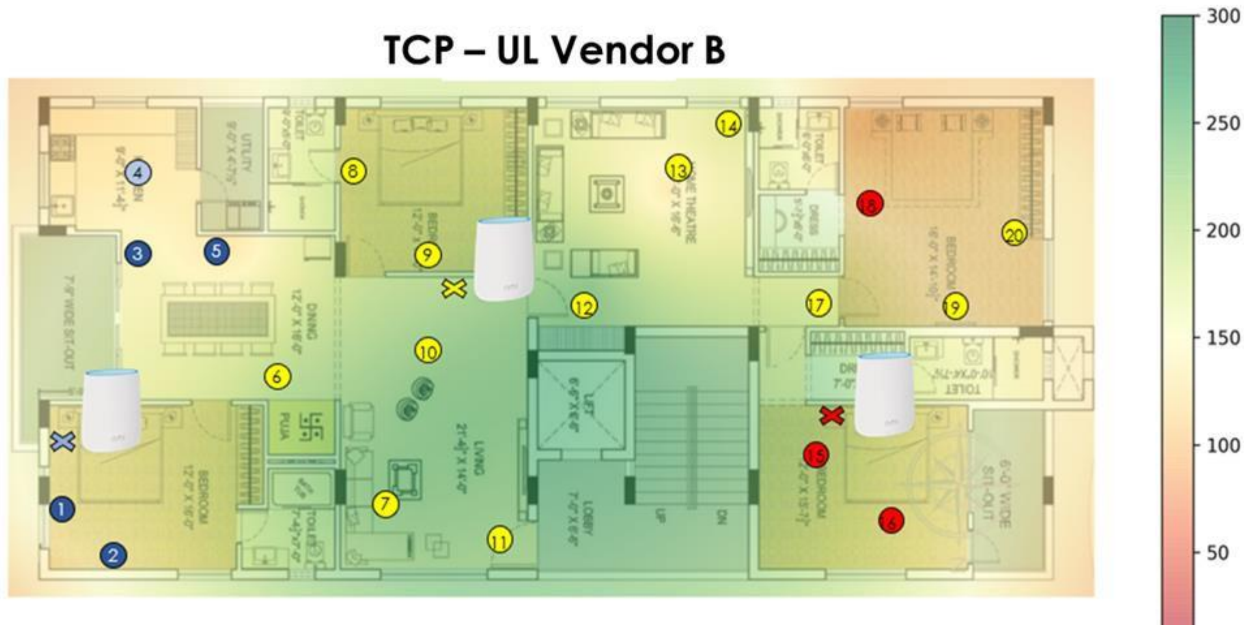
- Mesh nodes provide good coverage, as there were no dead zones on the 2500 sq ft floor.
- Observed less throughput at coordinates 4 and 5.
- Obtained the highest throughput at coordinate fourteen near GW.




TCP – UL Vendor A
300
250
200
150
100
50
0


RSSI Vendor A
−20
−30
−40
−50
−60
−70
−80


RSSI Vendor B
−20
−30
−40
−50
−60
−70
−80



Test Procedure

1. Turn on both the GW and Leaf nodes.
2. Mark 20 test points evenly distributed across the 2,500 sq. ft. area.
3. At each point, connect the test client to the AP.
4. Record the RSSI at the test point using a Wi-Fi analyzer or AP management tool.
5. Perform TCP uplink and downlink throughput tests (e.g., iperf) for a fixed duration (e.g., 60 s).
6. Note the results for each point.
7. Repeat step 5 for different traffic types.

Pass / Fail Criteria

- All twenty test points shall be successfully associated with either the Gateway (GW) or Leaf node.
- Continuous coverage shall be available across the entire 2,500 sq. ft. area with no dead zones otherwise fail.

Client connectivity with 30+ devices

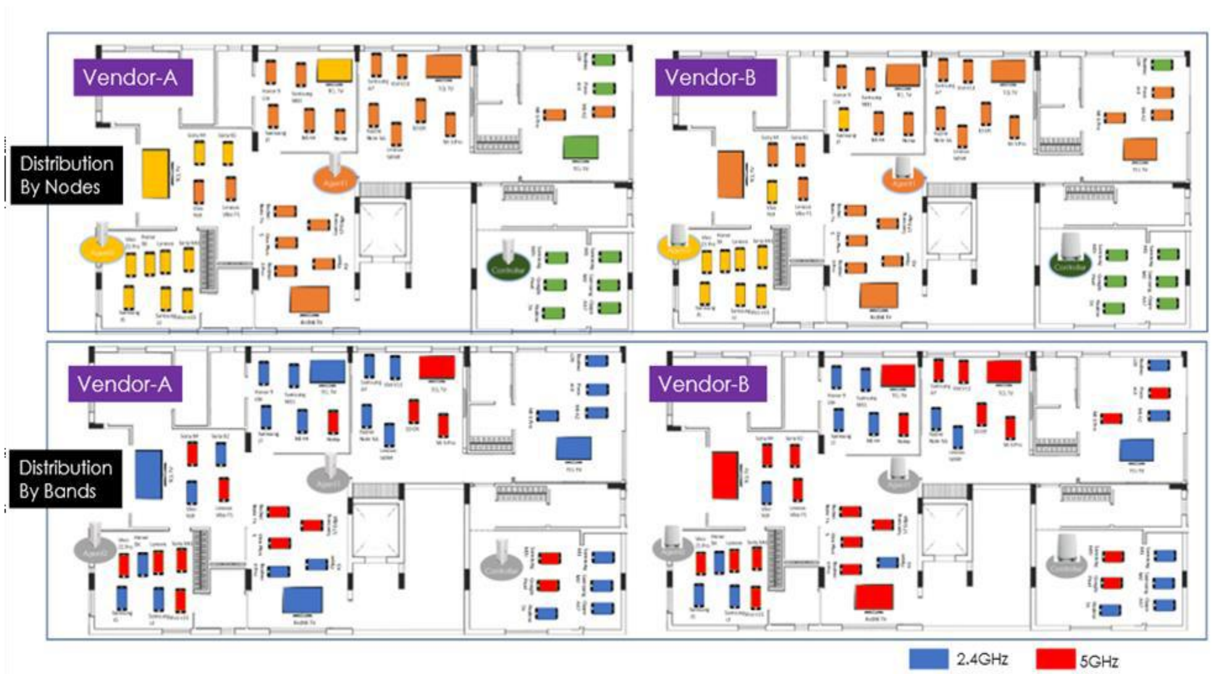
Objective

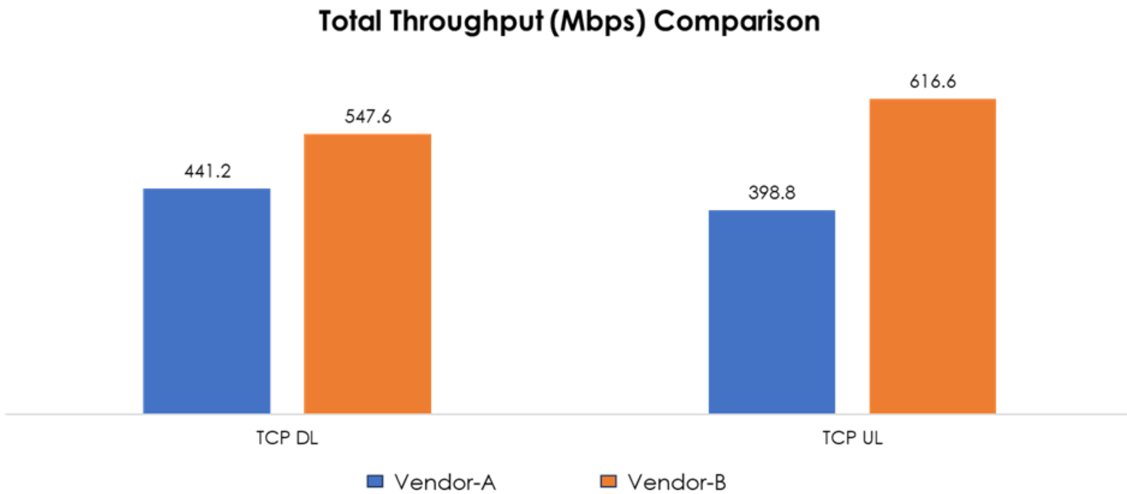
To evaluate and compare the client connectivity and throughput performance of the Device Under Test (DUT) in a real-world residential environment, simulating a high-density home deployment.

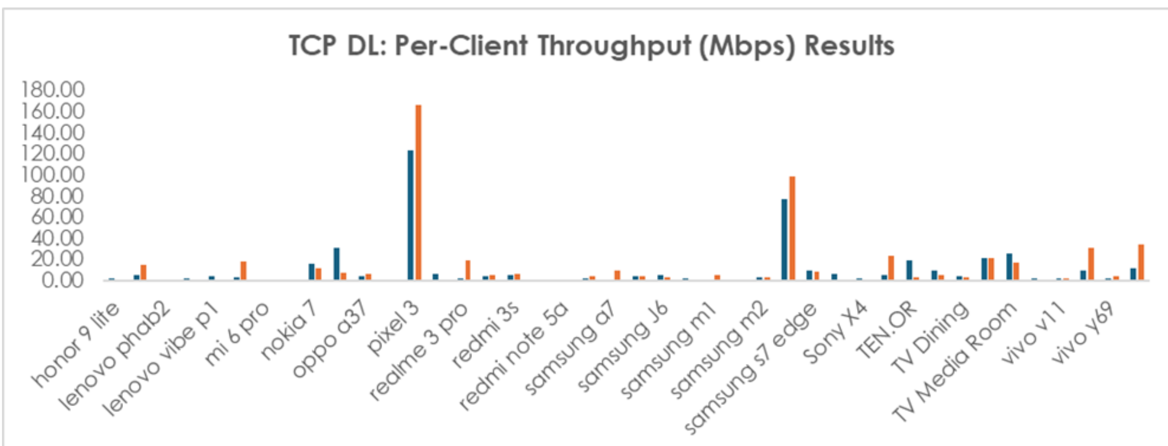
Observations

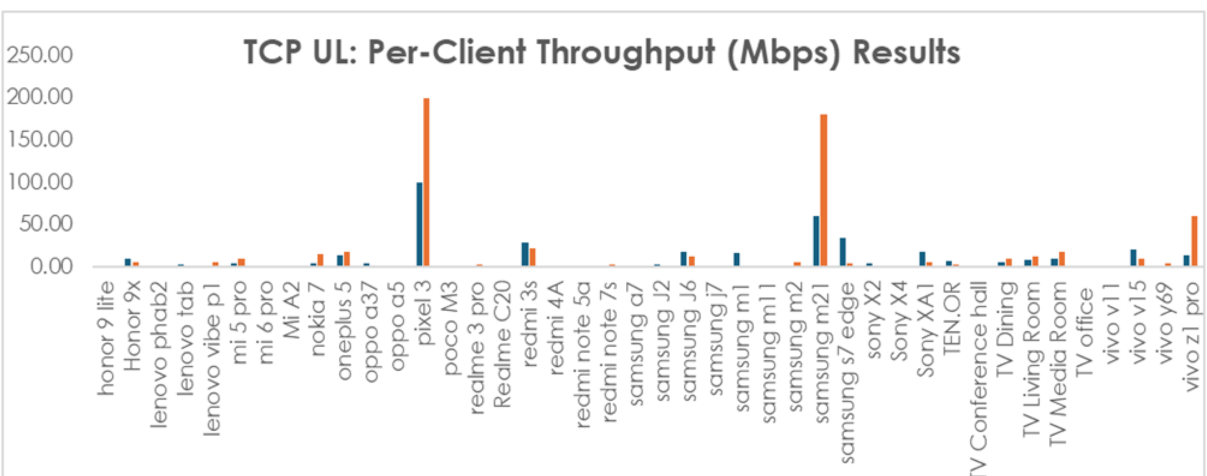
- All 30+ client devices were able to associate and remain connected to the DUT simultaneously across the 3,500 sq. ft. area.

- Vendor-A has more clients connected in 2.4GHz band than Vendor-B, which is possibly the reason why the overall throughput for Vendor-A is lower.
- There are no client disconnections or connectivity instability during concurrent TCP uplink and downlink traffic.




Total Throughput (Mbps) Comparison
441.2
547.6
398.8
616.6
TCP DL
TCP UL
Vendor-A
Vendor-B


TCP DL: Per-Client Throughput (Mbps) Results
180.00
160.00
140.00
120.00
100.00
80.00
60.00
40.00
20.00
0.00
honor 9 lite
lenovo phab2
lenovo vibe p1
mi 6 pro
nokia 7
oppo a37
pixel 3
realme 3 pro
redmi 3s
redmi note 5a
samsung a7
samsung J6
samsung m1
samsung m2
samsung s7 edge
Sony X4
TEN.OR
TV Dining
TV Media Room
vivo v11
vivo y69


TCP UL: Per-Client Throughput (Mbps) Results
250.00
200.00
150.00
100.00
50.00
0.00
honor 9 lite
Honor 9x
lenovo phab2
lenovo tab
lenovo vibe p1
mi 5 pro
mi 6 pro
Mi A2
nokia 7
oneplus 5
oppo a37
oppo a5
pixel 3
poco M3
realme 3 pro
Realme C20
redmi 3s
redmi 4A
redmi note 5a
redmi note 7s
samsung a7
samsung J2
samsung J6
samsung j7
samsung m1
samsung m11
samsung m2
samsung m21
samsung s7 edge
sony X2
Sony X4
Sony XA1
TEN.OR
TV Conference hall
TV Dining
TV Living Room
TV Media Room
TV office
vivo v11
vivo v15
vivo y69
vivo z1 pro

Test Procedure

1. Testing is conducted in a 3,500 sq. ft. single-level apartment using forty-two real Wi-Fi client devices distributed across seven fixed sections in a Mesh network.
2. TCP downlink and uplink tests are performed on all clients simultaneously to assess performance under multi-device load.
3. The same clients, placement, and test conditions are maintained for all APs to ensure a fair comparison.

Pass / Fail Criteria

- All client devices shall successfully be associated and remain connected throughout the test duration.
- The DUT shall sustain simultaneous TCP uplink and downlink traffic under multi-client load without crashes, reboots, or service degradation.
- Continuous coverage should be maintained across the test area with no dead zones impacting client connectivity or throughput.

Advanced Test Suite:

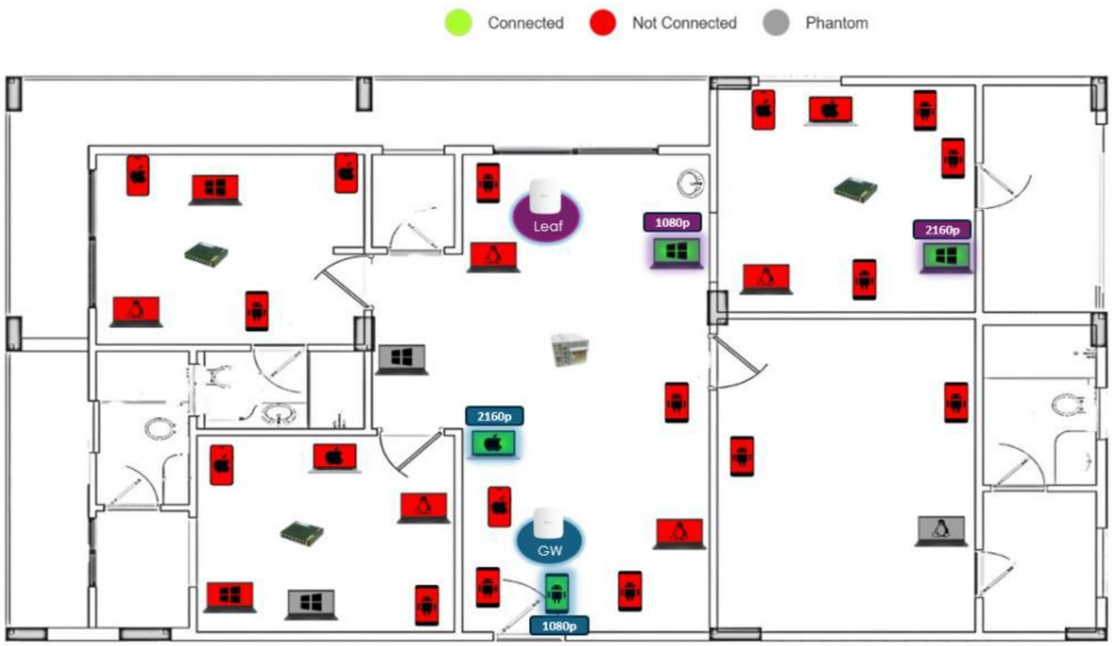
YouTube Streaming

Objective

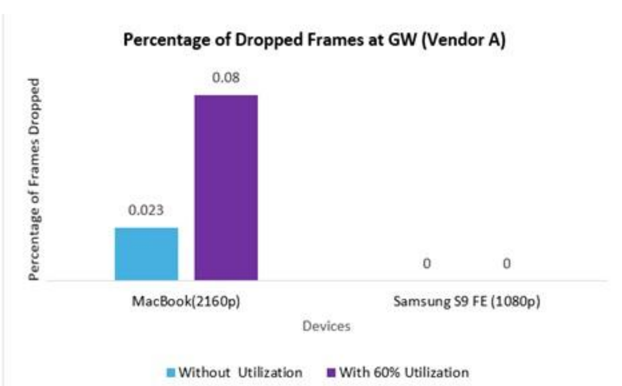
- Smooth YouTube streaming was observed on all clients with no buffering during the 1-hour test duration.
- Dropped frame count remained negligible and consistent under both low channel utilization (<10%) and high channel utilization (60%).
- Video playback performance was not impacted by increased channel utilization across 5 GHz and 6 GHz bands.

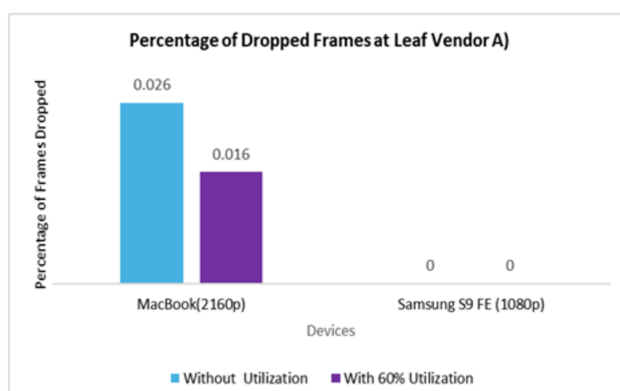
Observations

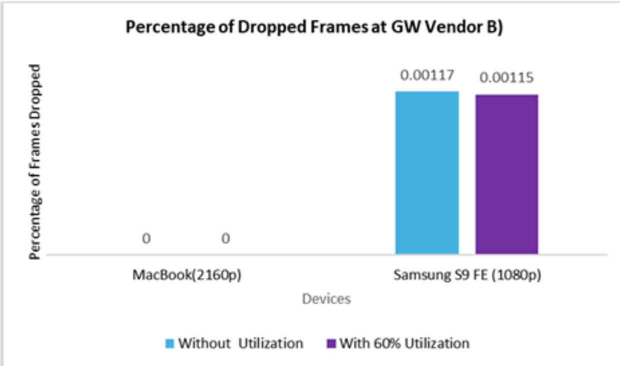
- During the entire test, no buffering was observed.
- The percentage of dropped frames when there is no channel utilization is the same as the dropped frames when the channel utilization is 60%.

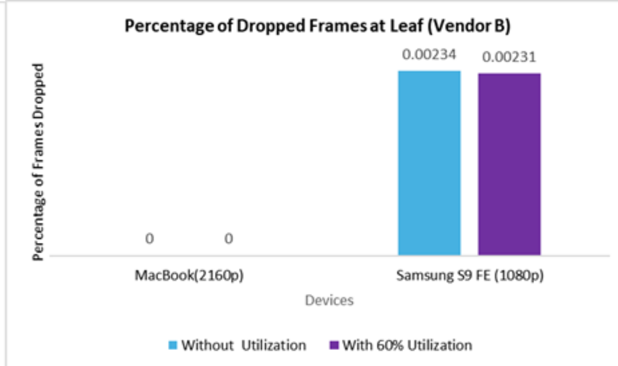


<table>
<tr><th rowspan="2">Model</th><th rowspan="2">Device Placement</th><th rowspan="2">Connected Node</th><th rowspan="2">Connected Band</th><th rowspan="2">Video Resolution</th><th colspan="2">Without Utilization</th><th colspan="2">With Utilization</th></tr>
<tr><th>Total Frames</th><th>Dropped Frames</th><th>Total Frames</th><th>Dropped Frames</th></tr>
<tr><td>Dell-V9Q</td><td>Kitchen</td><td>Leaf</td><td>6GHz</td><td>2160p</td><td>85428</td><td>2</td><td>86415</td><td>2</td></tr>
<tr><td>MacBook</td><td>Kitchen</td><td>Leaf</td><td>5GHz</td><td>1080p</td><td>86435</td><td>0</td><td>86407</td><td>0</td></tr>
<tr><td>MacBook</td><td>Guest Bedroom</td><td>GW</td><td>5GHz</td><td>2160p</td><td>85256</td><td>1</td><td>86377</td><td>1</td></tr>
<tr><td>Samsung S9 FE</td><td>Living Room</td><td>GW</td><td>5GHz</td><td>1080p</td><td>85056</td><td>0</td><td>85375</td><td>0</td></tr>
</table>









Test Procedure

1. Make sure the channel utilization is less than 10% on all the bands.
2. Connect two clients on each node.
3. Run the same test with 60% Channel Utilization on all the bands.
4. Set full HD and 4k resolution YouTube videos on connected devices and run for 1 hour duration.

Pass / Fail Criteria

- No video buffering or playback interruptions shall be observed under both low and high channel utilization conditions.
- Dropped video frames remain minimal and comparable when channel utilization increased to 60%, with no impact on selected video resolution.

Roaming with two or more nodes

Objective

To verify seamless client roaming between the root AP and leaf AP by monitoring continuity and connectivity while the client moves between coverage areas.

Observations

- Observed that one packet is lost while pinging to Google DNS, and no packets are lost from Gateway.

Ping Statistics	Vendor-A		Vendor-B	
	Gateway	Google	Gateway	Google
packets transmitted	601	703	612	723
packets received	601	702	612	723
packets loss	0	1	0	0
% packet loss	0%	0%	0%	0%
round-trip time (min)	1.59ms	16.15ms	1.49ms	10.16ms
round-trip time (max)	100.51ms	130.31ms	143.66ms	123.61ms
round-trip time (avg)	8.97ms	23.38ms	8.86ms	24.77ms

Test Procedure

1. First, connect the client (Android) to the root AP, and start the Ping session to the Gateway AP (192.168.4.1) and DNS of Google (8.8.8.8) with a ping interval of 200ms.
2. Start moving the client along the path outlined on the floor from the Root AP range to the Leaf AP range.

Pass/Fail Criteria

- The test will pass if there is no more than one ping failure. If there is more than one ping failure, the test will fail.

Roaming with Real Application

Objective

To verify service continuity while the client roams seamlessly between the Root AP and Leaf AP by monitoring ping continuity and connectivity while the client moves between coverage areas.

Observations

- Observed that one packet is lost while pinging to Google DNS, and no packets are lost from Gateway for Vendor-A.
- During YouTube streaming, there is one frame loss for Vendor-A compared to Vendor-B.

Ping Statistics	Vendor-A		Vendor-B	
	Gateway	Google	Gateway	Google
packets transmitted	611	705	623	721
packets received	611	704	623	721
packets loss	0	1	0	0
% packet loss	0%	0%	0%	0%
round-trip time (min)	1.79ms	16.75ms	1.19ms	11.16ms
round-trip time (max)	110.51ms	135.31ms	123.66ms	124.61ms
round-trip time (avg)	9.97ms	24.38ms	8.06ms	24.87ms

YouTube Streaming Statistics	Vendor-A	Vendor-B

Video Resolution	2160p	2160p
Total Frames	43361	50152
Dropped Frames	1	0

Test Procedure

3. First, connect the client (Android) to the root AP, and start the YouTube streaming and Ping session to the Gateway of Eero (192.168.4.1) and DNS of Google (8.8.8.8) with a ping interval of 200ms.
4. Start moving the client along the path outlined on the floor from the Root AP range to the Leaf AP range.

Pass/Fail Criteria

- The test will pass if there is no more than one ping failure and no service discontinuity; otherwise, it will fail.

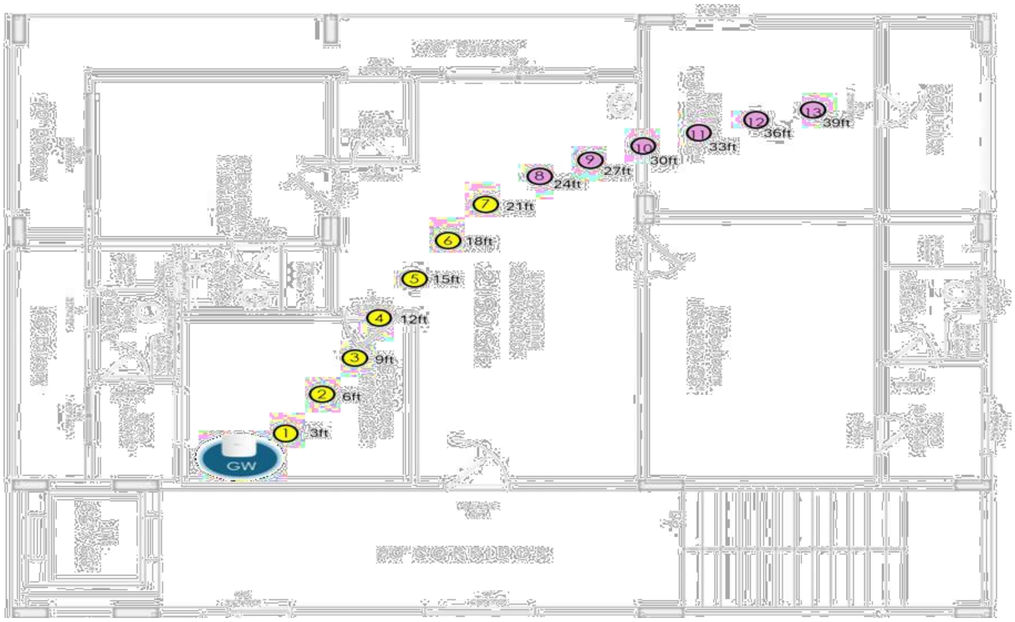
Performance Over Distance

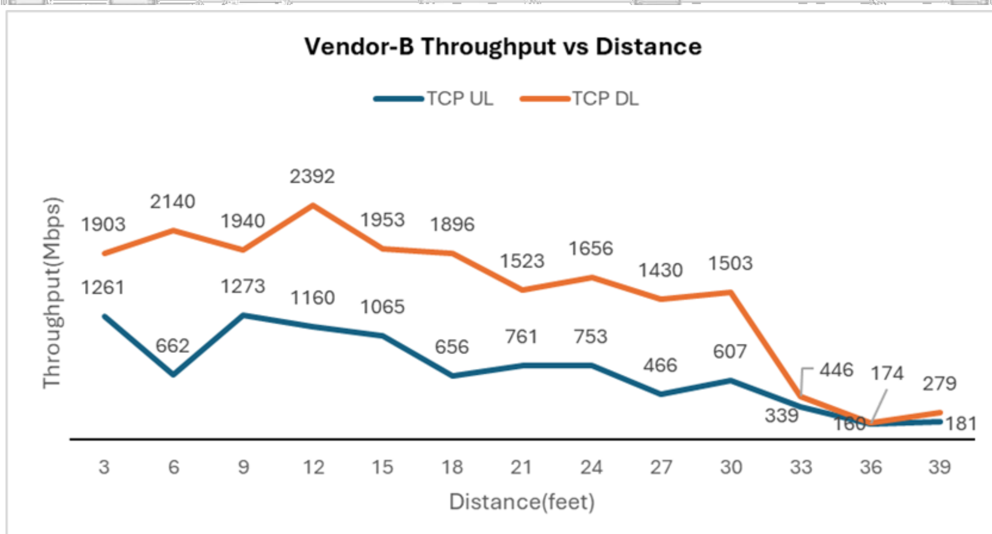
Objective

To evaluate AP wireless performance as distance increases under LOS and NLOS conditions by analyzing signal degradation, throughput variation, and maximum usable coverage.

Observations

- In LoS, better throughputs were observed compared to non-LoS for both vendor APs.
- For Vendor-A, in TCP DL, throughputs decreased with the increase in distance, whereas for Vendor-B, throughputs decreased with the increase in distance except at 12ft and 30ft distances, and till 30ft distance, TCP DL is > 1Gbps.
- In TCP UL, throughput increased to positions 5 and 6 compared to position four.
- For Vendor-B, at 27 ft distance, the client is toggling between 6GHz and 5GHz bands.
- With the increase in distance, the client steered from 6GHz to 5GHz and then to 2.4GHz bands, as expected for both vendors.





Vendor-A									
Position	Distance (ft)	Connected Band (GHZ)	Channel	RSSI (dBm)	PHY Rate (Mbps)	TCP UL (Mbps)	PHY Rate (Mbps)	TCP DL (Mbps)	Line-of-Sight (LoS)
1	3	6	117	-29	4323	1970	5764	2440	Yes
2	6	6	117	-32	4803	1770	4323	2430	Yes
3	9	6	117	-39	3843	1580	4323	2360	Yes
4	12	6	117	-42	2882	1560	3843	2160	Yes

5	15	6	117	-43	3458	1550	3843	1890	Yes
6	18	6	117	-45	3843	1580	3458	1640	Yes
7	21	6	117	-46	3458	1540	2882	1640	Yes
8	24	5	100	-48	1922	1170	2162	1210	No
9	27	5	100	-52	1441	942	1724	1090	No
10	30	5	100	-53	1441	854	1441	952	No
11	33	5	100	-57	721	485	721	483	No
12	36	5	100	-65	432	224	576	333	No
13	39	2.4	11	-55	77	29.6	432	188	No

Vendor-B									
Position	Distance (ft)	Connected Band (GHZ)	Channel	RSSI (dBm)	PHY Rate (Mbps)	TCP UL (Mbps)	PHY Rate (Mbps)	TCP DL (Mbps)	Line-of-Sight (LoS)
1	3	6	165	-43	5188	1261	5764	1903	Yes
2	6	6	165	-46	4803	662	5188	2140	Yes
3	9	6	165	-52	3843	1273	4803	1940	Yes
4	12	6	165	-54	3843	1160	4803	2392	Yes
5	15	6	165	-55	3843	1065	4323	1953	yes
6	18	6	165	-55	3458	656	4323	1896	yes
7	21	6	165	-59	2882	761	3843	1523	yes
8	24	6	165	-65	1729	753	3458	1656	no
9	27	6 (Band Toggling)	165	-68	1297	466	2882	1430	no
10	30	6	165	-62	1729	607	2882	1503	no
11	33	5	157	-57	721	339	961	446	no
12	36	5	157	-65	288	160	576	174	no
13	39	5	157	-68	432	181	576	279	no

Test Procedure

1. Place the client at 3 ft from the AP in LOS conditions.
2. Measure RSSI and perform TCP throughput tests at 3-ft incremental distances until the signal drops below a usable threshold.
3. Repeat the same test in NLOS conditions (e.g., through walls/obstructions).
4. Record distance, RSSI, and throughput for each point.

Pass/Fail Criteria:

- A decrease in throughput as distance increases is considered a pass.
- Irregular peaks and drops in throughput are considered fair performance.

Comprehensive Test Suite

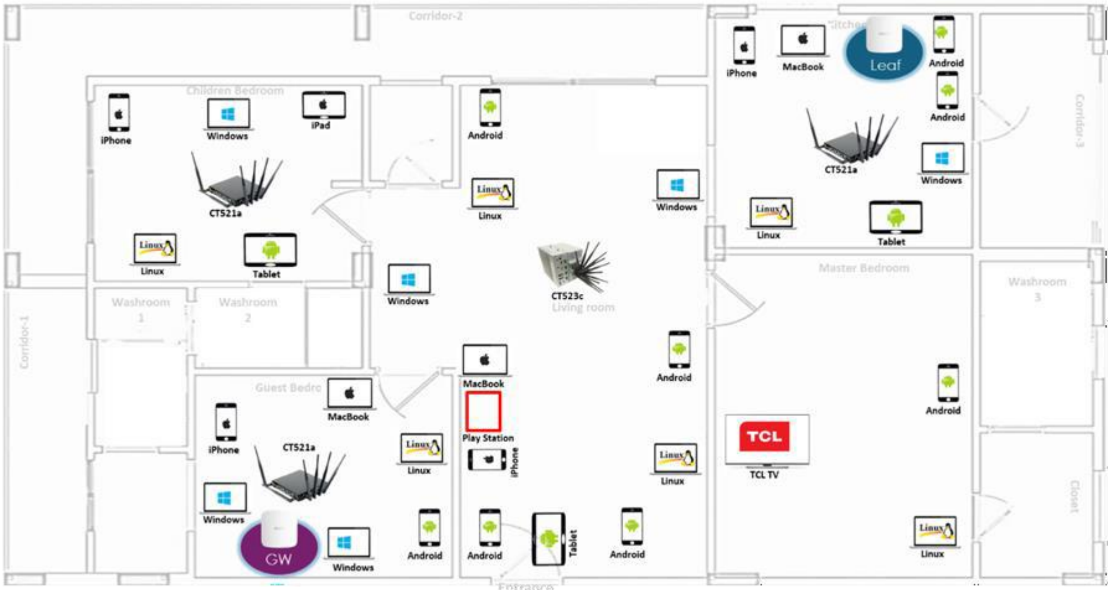
40+ IoT Devices Toggling Test

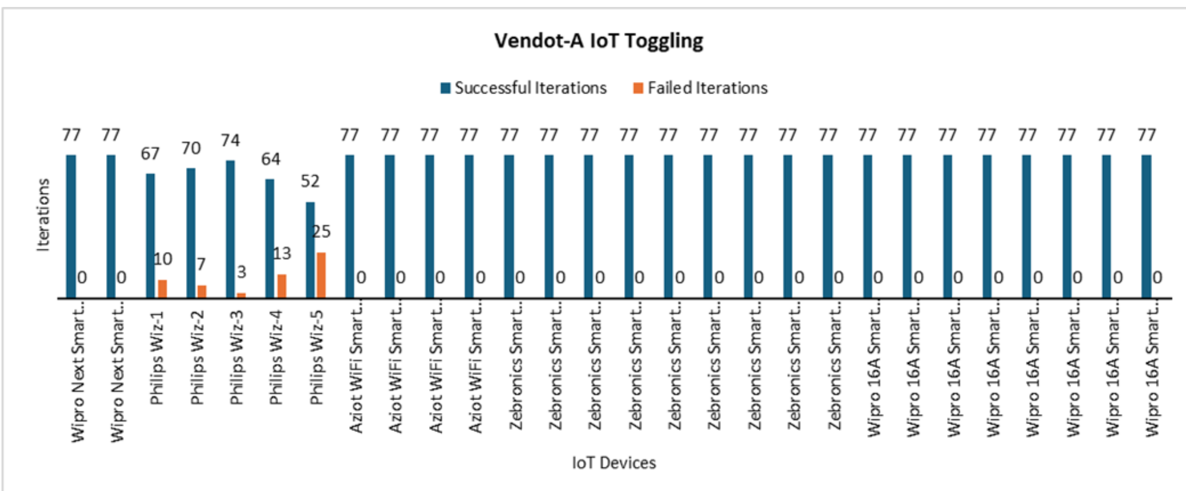
Objective

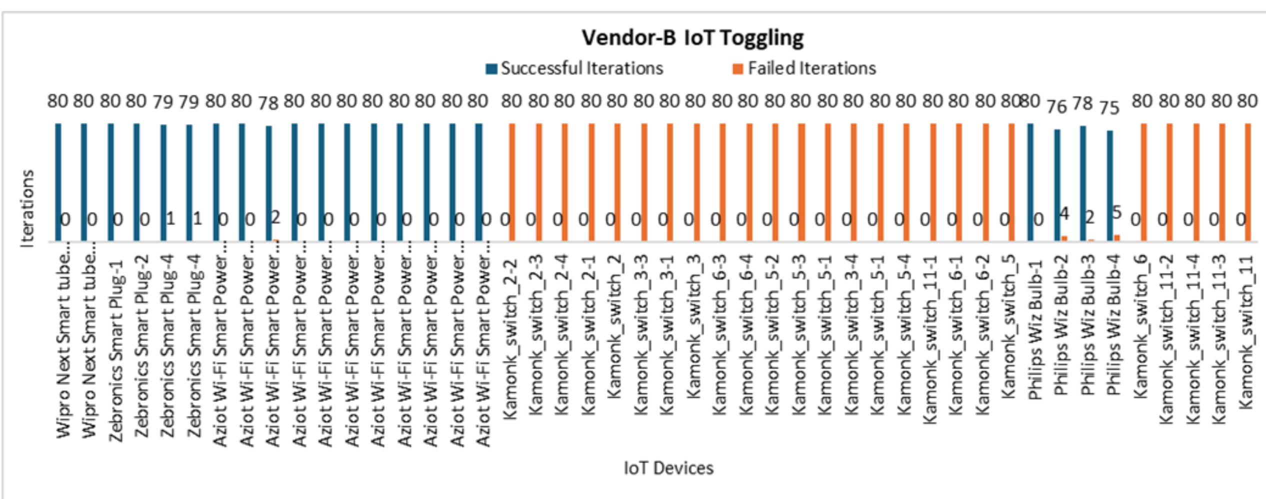
To evaluate the stability and reliability of the APs under high IoT device load by continuously toggling 40+ IoT devices and verifying AP stability, device connectivity, and recovery behavior over an extended duration.

Observations

- The APs did not crash or reboot while continuously toggling Wipro Next Smart tube lights, Philips Wiz Bulbs, Zebronics Smart Plugs, Wipro 16A Smart Plugs, and the remaining IoT devices are in a connected state.
- Though some of the devices failed to toggle, they are still in a connected state to the APs.


Corridor-2
Children Bedroom
iPhone
Windows
iPad
CT521a
Linux
Tablet
Android
MacBook
Leaf
Windows
Linux
Tablet
CT523c
Living room
Master Bedroom
Washroom 1
Washroom 2
Washroom 3
Corridor-1
Corridor-3
Guest Bedro
MacBook
Play Station
iPhone
TCL
TCL TV
GW
Closet
Entrance


Vendot-A IoT Toggling
Successful Iterations
Failed Iterations
Iterations
IoT Devices
Wipro Next Smart...
Wipro Next Smart...
Philips Wiz-1
Philips Wiz-2
Philips Wiz-3
Philips Wiz-4
Philips Wiz-5
Aziot WiFi Smart...
Zebronics Smart...
Wipro 16A Smart...
77 77 67 70 74 64 52 77 77 77 77 77 77 77 77 77 77 77 77 77 77 77 77 77 77 77 77 77
0 0 10 7 3 13 25 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0


Vendor-B IoT Toggling
Successful Iterations
Failed Iterations
Iterations
IoT Devices
Wipro Next Smart tube...
Wipro Next Smart tube...
Zebronics Smart Plug-1
Zebronics Smart Plug-2
Zebronics Smart Plug-4
Zebronics Smart Plug-4
Aziot Wi-Fi Smart Power...
Kamonk_switch_2-2
Kamonk_switch_2-3
Kamonk_switch_2-4
Kamonk_switch_2-1
Kamonk_switch_2
Kamonk_switch_3-3
Kamonk_switch_3-1
Kamonk_switch_3
Kamonk_switch_6-3
Kamonk_switch_6-4
Kamonk_switch_5-2
Kamonk_switch_5-3
Kamonk_switch_5-1
Kamonk_switch_3-4
Kamonk_switch_5-1
Kamonk_switch_5-4
Kamonk_switch_11-1
Kamonk_switch_6-1
Kamonk_switch_6-2
Kamonk_switch_5
Philips Wiz Bulb-1
Philips Wiz Bulb-2
Philips Wiz Bulb-3
Philips Wiz Bulb-4
Kamonk_switch_6
Kamonk_switch_11-2
Kamonk_switch_11-4
Kamonk_switch_11-3
Kamonk_switch_11

Test Procedure

1. Power on GW and Leaf nodes.
2. Connect 50 IoT devices (smart plugs, bulbs, switches, etc.) to the nodes.
3. Initiate an automated script or control application to continuously toggle all IoT devices ON/OFF at defined intervals.
4. Monitor AP connection stability and device responsiveness.
5. Observe any device disconnections, command delays, or failures to respond.
6. Maintain the toggling process for a sustained duration (e.g., 8 hours).
7. After the test, verify that all devices reconnect automatically if disconnected during stress.
8. Record any AP crashes, reboots, or performance degradation.

Pass / Fail Criteria

- The APs should maintain stable performance with no noticeable degradation impacting overall network stability under sustained IoT activity.

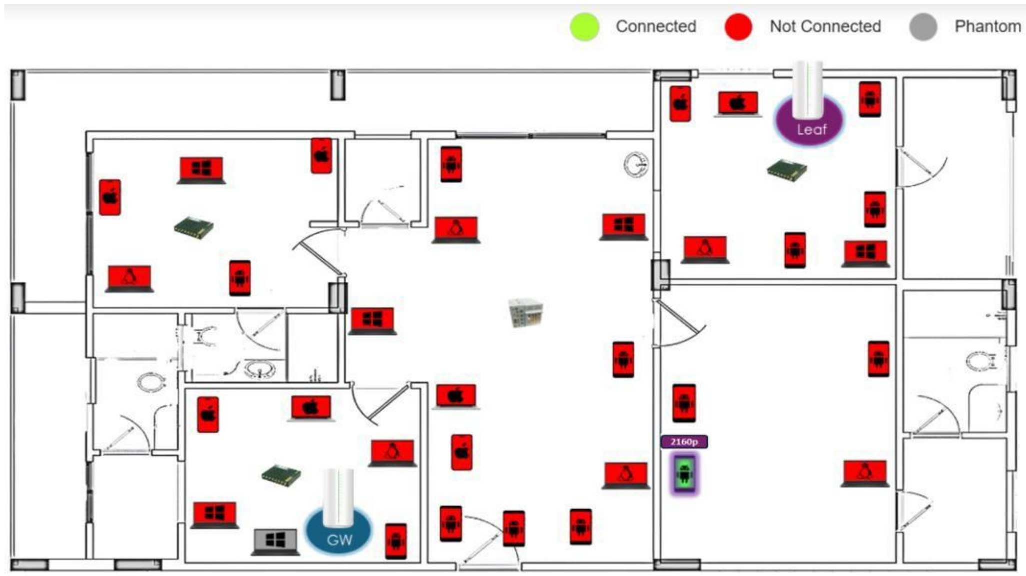
15–20 IoT + Wi-Fi Clients Stability during continuous toggling of devices along with traffic

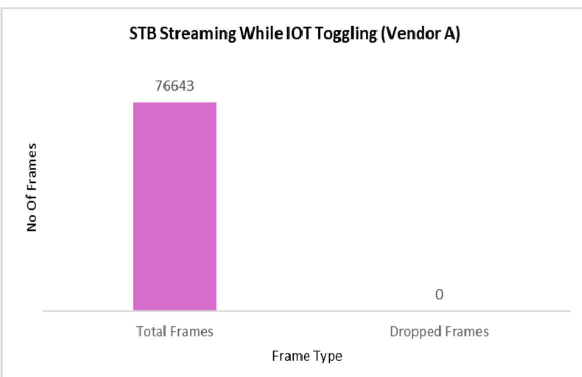
Objective

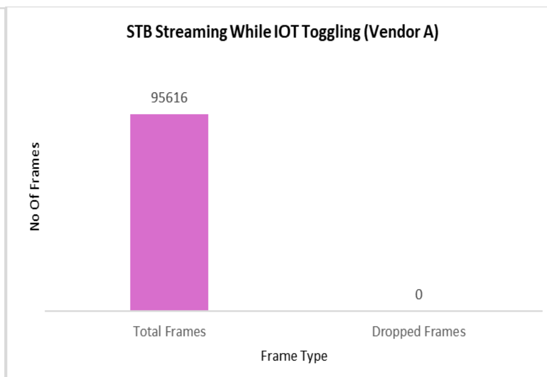
To evaluate network stability and performance when 15–20 IoT devices are continuously toggled while active Wi-Fi clients generate real-time traffic, and to verify that user-experience–sensitive applications remain unaffected.

Observations

- Despite continuous toggling of IoT devices, the STB video stream on YouTube showed zero dropped frames, no buffering, and no video freezes, indicating stable performance.







Test Procedure

1. Connect the STB to the network and start a YouTube video stream.
2. Continuously toggle multiple IoT devices on/off for 30 minutes.
3. Monitor the STB for buffering, no. of dropped frames, and video freezes.

Pass/ Fail Criteria

- All IoT devices shall remain connected and responsive, with any temporary recovery automatically.
- The AP shall remain stable with no crashes, reboots, or noticeable performance degradation during the test.

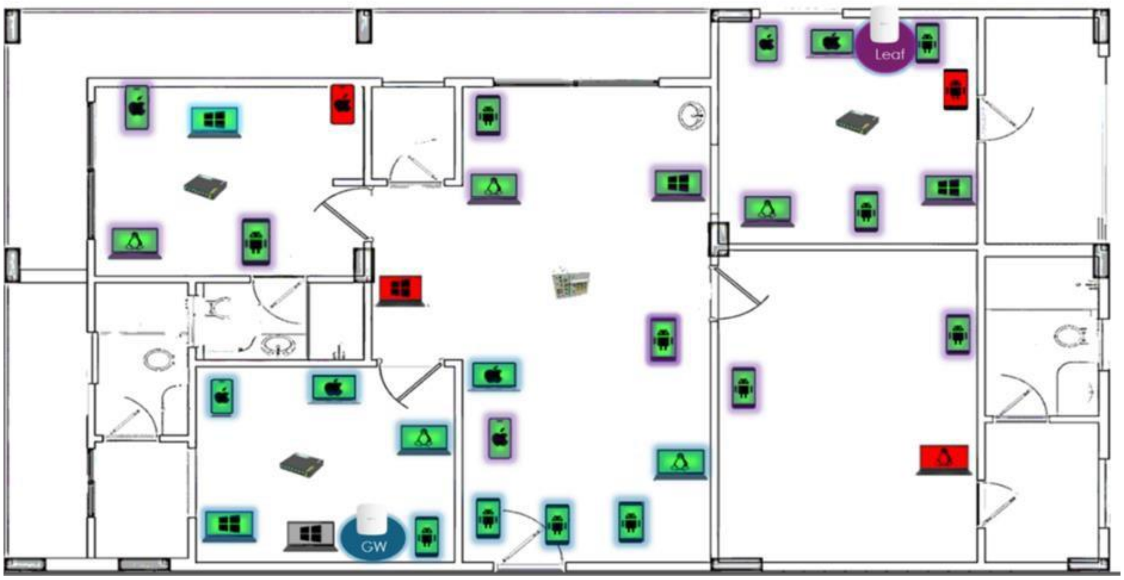
Mesh Reliability Stress Testing

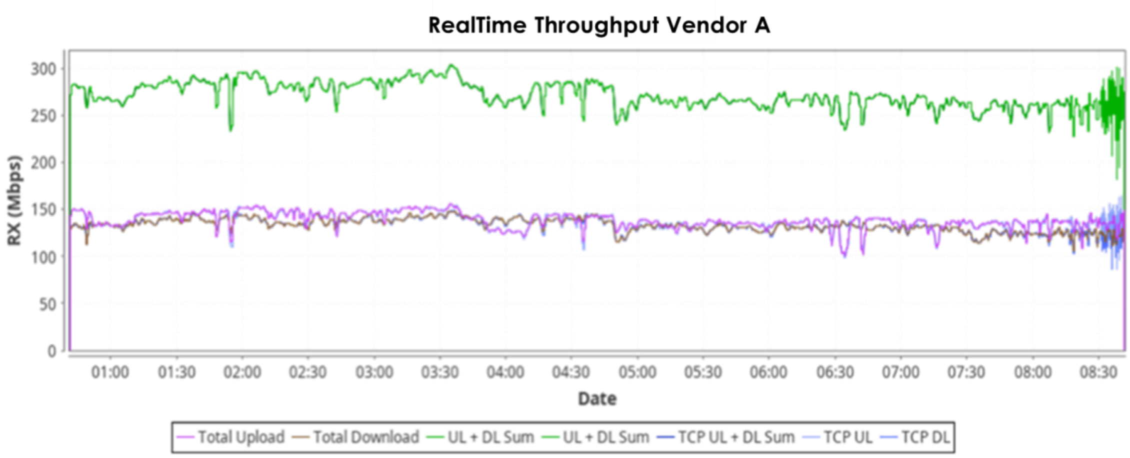
Objective

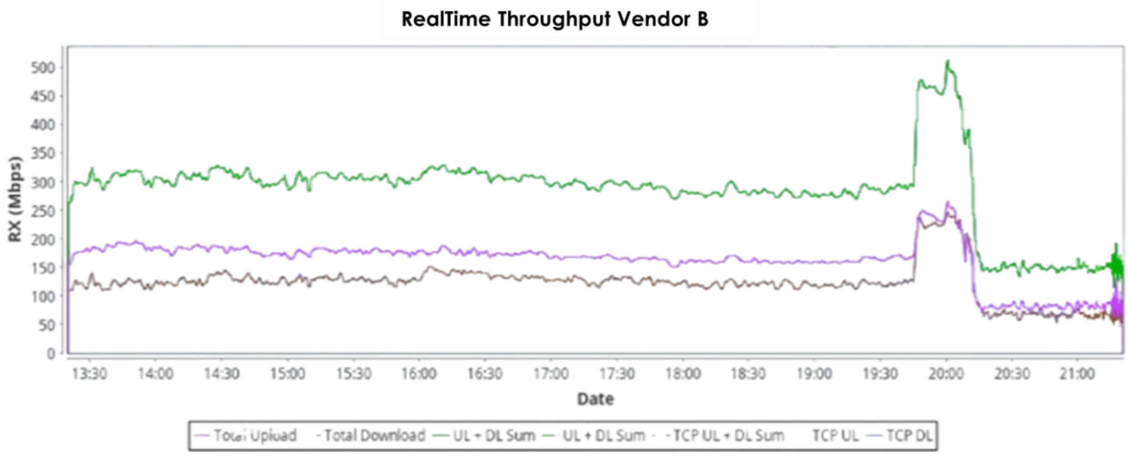
To verify the stability and throughput consistency of the mesh network under sustained high client load over an extended duration.

Observations

- The APs did not crash or reboot even under high stress.
- The throughput is stable during the 8-hour test, with no major drops or sudden fluctuations. Both upload and download rates are consistent.







Test Procedure

1. Ensure the mesh network is set up with the GW and Leaf-1 operational.
2. Connect a total of fifty clients, distributed between GW and Leaf-1
3. Maintain the stress test for eight continuous hours.
4. Measure throughput on both uplink and downlink during the test at regular intervals.

Pass/ Fail Criteria

- The mesh network shall remain stable throughout the 8-hour stress test with no AP crashes, reboots, or mesh link failures.
- All connected clients shall remain associated with the Gateway or Leaf node, with no prolonged or repeated disconnections.